COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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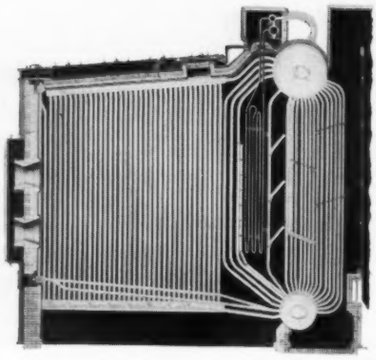
Hearst Photo Features

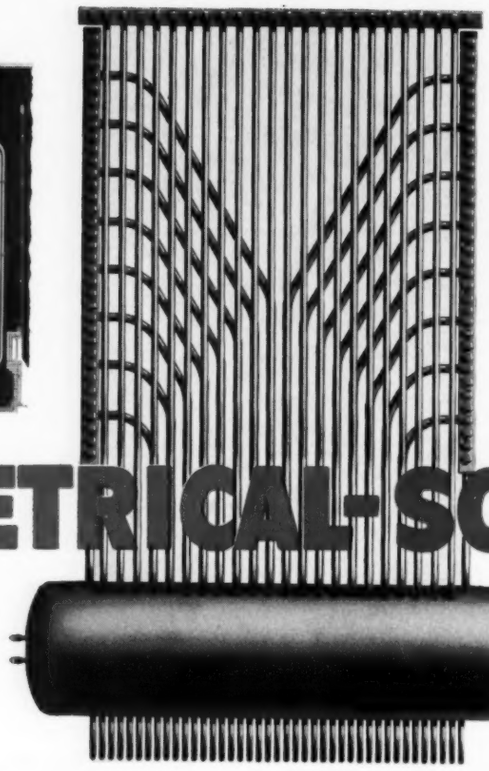
A.S.M.E. Symposium Discusses High-Pressure Operating Experience

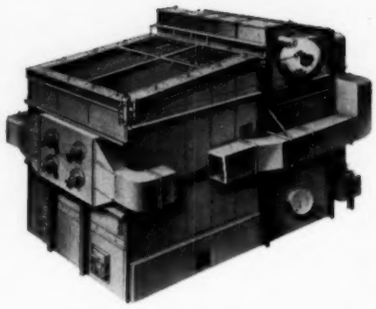
Orsat Checking Chart

Coal and Gas

Method of Heat Transfer Through Insulation







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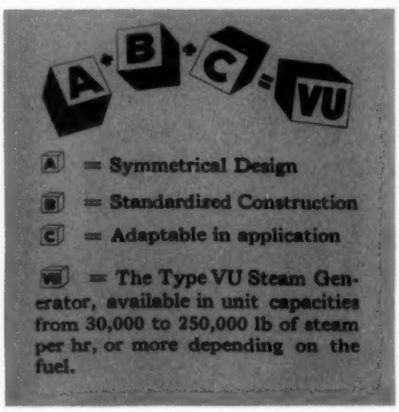
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VOLUME ELEVEN NUMBER SIX

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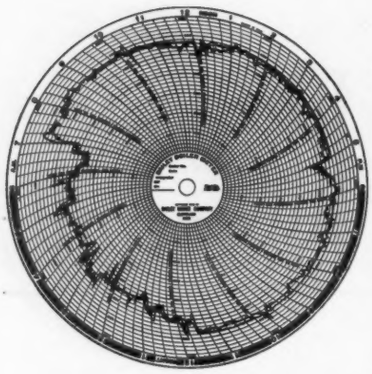
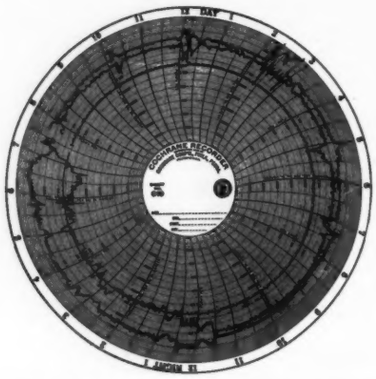
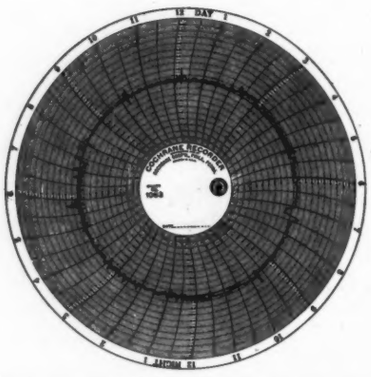


Steam-flow-air-flow chart shows a typical day's load on The Derby Gas & Electric Company's Integral Furnace Boiler. Rated capacity is 125,000 pounds of steam per hour.



Water flow, middle curve, follows load accurately despite changes in water pressure, outer curve, while steam pressure, inner curve, holds constant at 675 pounds gage.



Water level is stabilized within close limits throughout the day. Maximum variation is only plus or minus one inch, with level rising slightly as load increases.

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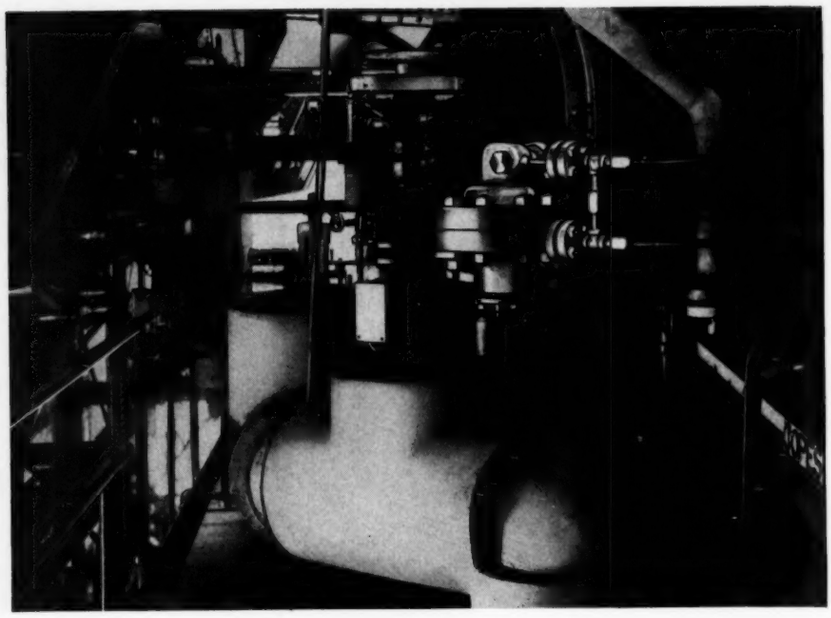

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EDITORIAL

High-Pressure, High-Temperature Operation

Judging from the attendance and interest shown, the high-spot session of the A.S.M.E. Annual Meeting in Philadelphia was the panel discussion on operating experiences with high-pressure, high-temperature superimposed installations. Such frank discussion by men responsible for operation does much to clarify the thinking of those having to do with the planning, design and selection of equipment for such installations.

It will be recalled that a similar session was held at the Annual Meeting two years ago in New York at which time most of these topping plants had just emerged from their initial operating periods. Most of the papers then revealed many difficulties incident to new designs and to operation under advanced steam conditions. This year's papers and discussions related how these difficulties had been overcome or are in the process of being corrected, and indicated that, in the light of experience gained, the availabilities are now practically equivalent to those of low-pressure plants.

Disregarding numerous minor difficulties, the major troubles incident to high-pressure, high-temperature conditions, as one speaker pointed out, have concerned circulation, carryover and slagging of heat absorbing surfaces. The first two are now well in hand but the third is still a problem with certain coals, although progress is being made toward a solution. Another difficulty present in many of the installations has been failure of blading in the impulse stages of the high-pressure turbines. Speed, temperature and the method of admitting the high-pressure steam seem to be contributing factors, but the problem is being approached through cooperative research on the part of turbine builders and the operating companies.

It has been suggested that, while much progress has been made in designing for creep, there may be other factors which prevent certain metals stressed at high temperature from withstanding additional strain to the extent possible with lower temperatures. Recent researches along this line have indicated that further advances should be approached cautiously.

Fixing Bituminous Coal Prices

An announcement by Secretary Ickes that the Bitumious Coal Division of the Interior Department has now completed the presentation of Government testimony on minimum prices for bituminous coal contains a reference to the extent of these latest hearings. In addition to division officials, fifty-seven producer's board representatives, forty-eight individual producers and representatives of seven consumers have testified. More than eighty attorneys were directly engaged in the proceedings, and the testimony and cross-examinations have been voluminous, that of one producer alone having covered eighteen hundred pages of the official record.

When one considers that this was preceded by numerous lengthy hearings of the district boards, the magnitude of the task of fixing minimum coal prices becomes apparent. It would be impossible to estimate the time and expense involved, not only in the work of the present board but also that of the former Commission.

In view of the apparent division of opinion within the coal industry as to the benefits likely to accrue to it, the prospect of higher prices to industrial consumers of coal, and the questionable workability and permanency of such price-fixing, there appears justification for the contention that the results may not be commensurate with the expenditure of time and money. Perhaps the chief beneficiaries will have been the lawyers.

The Forthcoming Census

The coming year will be a census year in which the Government will take stock of the people and the business resources of the nation. On January 2, 1940, the Census of Business, of Manufacturing, and of Mines and Quarries, will begin. This will cover operations for the calender year 1939. Approximately three million business concerns and two hundred thousand manufacturing plants will be covered by twelve thousand enumerators, and it is expected to have the field work completed within four or five months, so that basic facts can be published before the end of the year. The Census of Population, Agriculture and Housing will start on April 1.

The Census of Business will be most comprehensive and will contain a wealth of current facts vital to management, sales promotion, marketing and financing. Compliance in the furnishing of information asked is required by law but data concerning any individual business are confidential and inviolable by act of Congress.

The Manufacturing Census will cover plant equipment and depreciation as well as information concerning employees and the value of manufactured products and construction work. Special emphasis is being placed on power plant equipment installed in manufacturing plants, including expenditures for new equipment, depreciation and obsolescence. However, a perusal of the questionnaire reveals that, despite provision for complete information on all types of prime movers, electric motors, fuel used and electricity produced or purchased, there is nothing concerning steam generating equipment. The omission of such important and basic data is difficult to understand, inasmuch as the Census Bureau has for years been importuned to include it. While it is true that the Bureau has, for some years, issued monthly reports on the sales of boilers and fuel burning equipment, this gives no clue to the number of such units installed in the various industries nor to their state of obsolescence.

A.S.M.E. Symposium Discusses High-Pressure Operating Experience

It will be recalled that during the 1937 Annual Meeting of the American Society of Mechanical Engineers a session was devoted to experiences with ten high-pressure, high-temperature installations which, at that time, were in their initial periods of operation. At this year's annual Meeting in Philadelphia, December 4 to 8, the program included a "Power Panel Discussion" in which reports of two years' subsequent operation of four of these original installations were given. During this period many of the initial difficulties have been overcome and the availability of the units has been greatly improved. Following are excerpts from these reports and a digest of the discussion.

Superimposed Installation at Waterside Station, New York

By J. C. FALKNER Prod. Mgr.,
Consolidated Edison Company of New York

THERE have been very few changes in operating procedures at the Waterside Station since the installation of the high-pressure units two years ago. Such changes as have occurred have dealt mainly with the method of makeup, the method of watching water levels, chemical feed, sampling of boiler water and the taking of steam samples.

High-Pressure Turbine-Generators

Turbine generator No. 4, a 50,000-kw Westinghouse unit, was removed from service shortly after it was placed in operation September 10, 1937, in order to permit that company to remove the two rows of impulse blades. There were a few cracks in the shroud on the first row of impulse blades but in neither row were there any blade failures. With these blades out this machine operated without difficulty, except for a few shutdowns for inspection of the governor and bearings, until February 1939 when it was found that the bearing in the head end of the high-pressure turbine and that near the flexible coupling between the main and feed-heating turbines showed cracking which necessitated rebabbitting.

In March 1939, the unit was opened, due to a rub being heard while the machine was being taken off the line. It was found that the coupling on the main-turbine side of the stub shaft between the main and feed-heating turbines had broken. The collar of the thrust bearing for the main unit is located on this stub shaft. The breaking of the coupling made the thrust bearing ineffective for the main unit and the spindle moved so that the high-pressure dummies rubbed and seized. One broken blade was found in the tenth stage and three pieces of shroud bands were missing in the same row. The fact that the rotating parts of the high-pressure seal were integral with the spindle necessitated a complete new spindle. The author is of the opinion that the coupling broke first, as there had been a slight change in alignment when the rebabbitted bearings were installed.

The new spindle with new blades, new dummies and a new design of stub-shaft coupling were installed in June 1939, and the machine has run satisfactorily since this change with the one exception of the governor which still has a hunting characteristic.

Until January 1939, there was practically no evidence of blade fouling on either of the two high-pressure turbines. But beginning then there was a capacity loss on the General Electric No. 5 turbine from 42,000 to 36,000 kw, taking place gradually over a 3-month period. The turbine was then taken off the line and allowed to cool for 12 hr, after which it was washed out with low-pressure steam, without any water being admitted for desuperheating. This method of cleaning did not prove effective and on March 20, the machine was again taken out after provisions had been made to admit water with the steam. The washing lasted for a period of from 6 to 8 hr with a steam pressure of 15 to 20 lb, which was sufficient to turn the turbine. The steam temperature was 215 to 220 F. This method of cleaning proved satisfactory and load on the turbine was increased to 42,000 kw. Ten days later it again showed signs of fouling and it became necessary to wash the turbine on June 10. After the third washing, the load was again brought back to 42,000 kw from 38,000 to which it had dropped.

No. 4 Westinghouse unit showed no sign of fouling when it was opened in March. It was first thought that the fouling of No. 5 unit was caused by the eliminator screens in the 5A and 5B boilers being plugged, thus allowing the solids to go out with the steam. Checks showed that the carry-over was less than 0.3 ppm which was as low as could be measured. A different method of blowing down the boilers has practically eliminated the fouling which proved that it is necessary to wash out lower waterwall headers and mud drums, while the boiler is off the line at intervals of not over two weeks.

On No. 4 unit there was a double frequency vibration on the generator end which was caused by the two-pole

field of the generator. This trouble was eliminated when the machine went back into service as the field has been provided with slots to compensate for the lack of pull on the sides 90 deg from the field coils. No vibration has been experienced on either of the high-pressure turbines.

The Westinghouse unit uses an average of 10 cu ft of hydrogen per day, and the General Electric unit an average of 30 cu ft. There has been no trouble due to the use of hydrogen in either machine.

Starting and Stopping

Both high-pressure units are started up integrally with the boilers; that is, as soon as there is a pressure of 200 lb in one of the boilers, the turbine is gradually brought up to 200 rpm, where it is held for approximately 1 hr. The exhaust from the turbine is used in the station auxiliary steam line at 5 lb back pressure. The pressure is then brought up and, when it reaches 600 lb, the exhaust steam is cut into the 200-lb header. From this point, 1 hr is allowed to bring the machine up to full speed.

In stopping the unit, no special precautions are taken other than those used on any low-pressure unit, with the exception, however, that the machine is kept on the turning gear for a period of time varying from 24 to 48 hr when stopping the Westinghouse machine and 24 hr for the General Electric machine.

There is a rise in the exhaust-casing temperature immediately after shutdown up to 670 F. This temperature has caused no trouble to date.

High-Pressure Boilers

The ash composition and the fluid temperature have a great influence on the cleaning problems of the high-pressure boilers. Coal that has an initial ash-deformation temperature of not less than 2200 F has been determined upon after 2 yr of operation. At present, the cleaning of boilers is done by hand lancing and by taking the boiler off the line for a few hours, about twice a week, thus allowing the slag formation on the tubes and side walls to cool and fall off.

Illuminating gas from the street mains is used in bringing the boilers up to pressure and also to ignite the pulverized fuel. A period of 5 to 6 hr is taken to bring the boiler up from cold. The gas is ignited by an electrical "glow-bar" which is located directly in the path of the gas.

The temperature of the steam is 900 F and is controlled with a flue-gas bypass around the superheater. This control has worked satisfactorily and it has been possible to maintain the desired temperature over all ranges of load. The outlet temperature of the exhaust steam leaving the turbine governs the steam temperature entering the turbine as the low-pressure units now installed are not built to use steam at a temperature much over 525 F.

The flame stability has been satisfactory at all loads above one-third of the rated capacity of the boiler. A pulsation in the furnace has been experienced, the cause of which the boiler manufacturer is attempting to ascertain. A new primary-fan inlet is being tried out as tests point to the fact that the initial pulsation starts at that point.

Mill Performance

The performance of the mills has been uniformly good. They give a fineness of 80 per cent through 200 mesh, 96 per cent through 100 mesh and 99 per cent through 60 mesh. The mills run very quietly, and very little trouble has been experienced outside of the replacement of mill rollers after their normal expected life. The average life of the rollers is 85,000 tons; scrapers, 18,000 tons; and bull rings 85,000 tons. Only two grades of coal have been used on these mills; namely, Coleman "Colver" and Weaver "Revloc." As these two coals are the only coals used, the data on the sensitivity is rather limited.

Feedwater Treatment, Boiler Concentration and Internal Cleanliness

The Hall Treatment is used in these boilers, and consists of an average of 86 lb of disodium crystallized phosphate and 21 lb of sodium hydroxide per 24-hr day for two boilers. The phosphate is introduced directly in the boiler drum, while the sodium hydroxide is added by gravity to the boiler feed between the deaerator and the feed-pump suction. Samples of boiler water are taken three times per day and analyzed for sodium hydroxide, sodium chloride and sodium phosphate.

The boiler concentration is held at 450 to 500 ppm, but it is thought that by the use of boiler-drum baffles, which have now been installed, the boiler concentration can be carried as high as 800 ppm without excessive carry-over. Small amounts of scale were found in the boiler tubes, while the drum was free from scale, and very little deposit was found on the side-wall tubes.

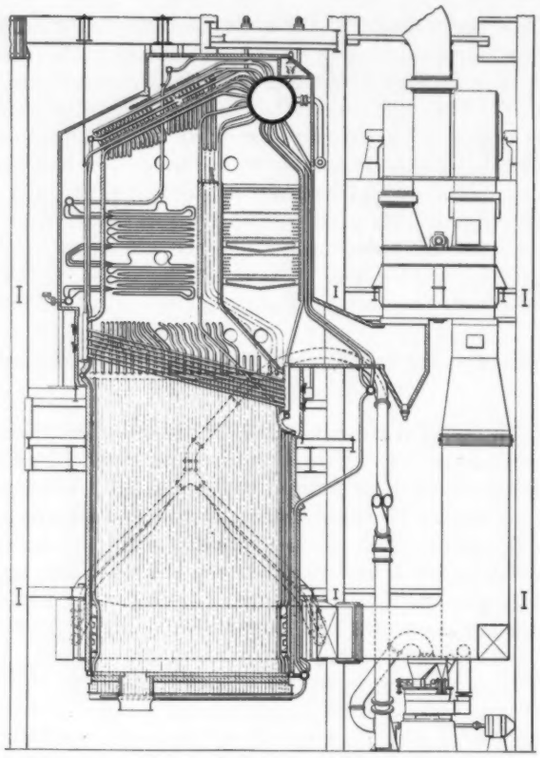
On two occasions, a side waterwall tube ruptured, and as the feed lines for both boilers supplying one unit come off the same header, the pressure dropped, thereby necessitating the immediate removal of the other boiler from the line. Another shutdown occurred when the automatic valve controlling the feedwater level in the drum stuck, and the water tender, while endeavoring to put the valve on hand operation, jammed the valve in such a manner that it closed, and the boiler had to be taken off the line. No shutdowns due to loss of feedwater to the boiler feed pumps have occurred.

Boiler Feed Pumps

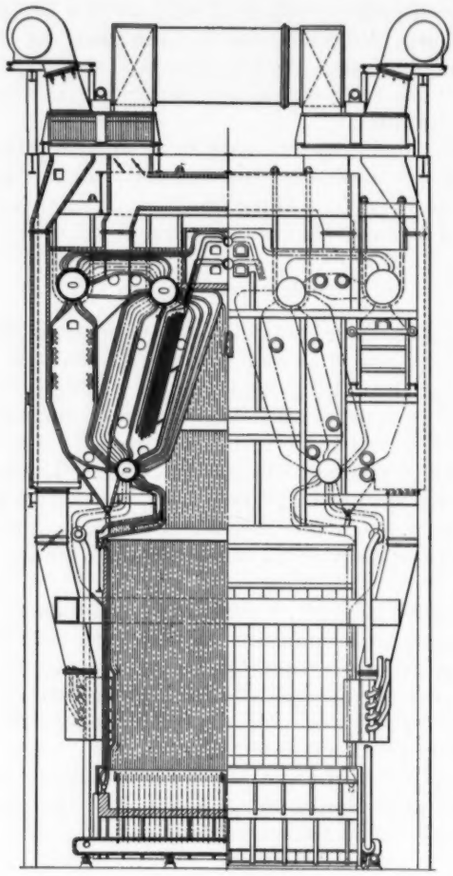
Four of the six boiler feed pumps now in use are motor-driven; the remaining two being driven by steam turbines. One of the difficulties experienced with the steam-driven pumps has been the leakoff valve from the outlet header to the suction header, which failed on several occasions. The trouble was caused by an excessive drop across the valve and this was finally overcome by putting two valves in series with a pipe made with labyrinth orifices in it, in order to help in building up a resistance to the water flowing through the valves. The pump manufacturers asked that the steam-driven boiler feed pump always be operated with the by-pass valve partly cracked so as to permit some water to pass through the pump at all times.

Air Preheaters

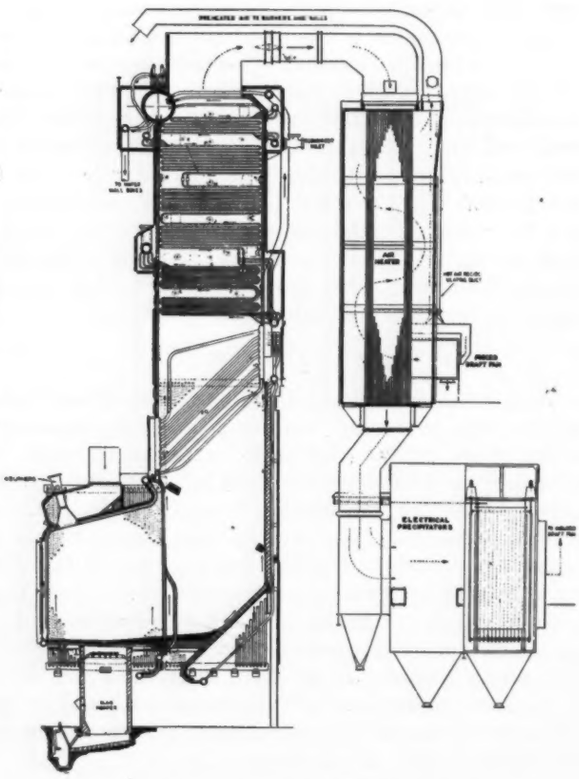
There has been no means of preventing condensation in the air preheaters during the starting up of boilers or while operating at light loads, and this has caused fouling with the consequent loss of capacity. An experiment



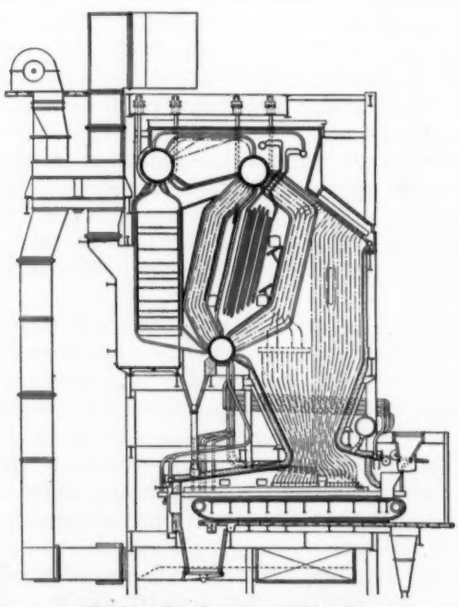
One of four units of Waterside Station, New York



Logan unit of 1,000,000 lb per hr capacity



One of two units at Fisk Station, Chicago



Stoker-fired unit at Omaha

Sections through the steam generating units discussed

(These are reproduced for the convenience of the reader, only one having been included in the papers)

in cleaning was tried using a movable air jet, which blew down from the air-inlet side of the heater. The nozzle was so adjusted that it would move in and out so that all parts of the surface were blown every 2 or 3 hr. Compressed air at 125 lb was used. Steam-jet soot blowers originally installed operated partially satisfactorily. A bypass around the air preheaters has been installed on Nos. 4A and 4B boilers and, if it proves successful, a similar bypass will be installed on Nos. 5A and 5B boilers.

The most successful method of cleaning air preheaters is by washing them with boiler feedwater which usually restores the draft drop through the air preheaters to its original figure.

Deaerators

It has been found that, when the steam pressure in the deaerator is kept above $2^1/_2$ lb, the deaerator will give almost 100 per cent deaeration. If, however, the steam pressure is allowed to vary for any reason, there will be a certain amount of oxygen fed into the boiler.

The steam to the deaerator is controlled by a regulating valve at the feed-heating turbine. The operation of this valve has been investigated and it was found that there is an intermittent flow of steam from the feed-heating turbine to the deaerator with this type of control. A new control valve will be installed at the deaerator to insure sufficient steam at all times for complete deaeration.

The feedwater is deaerated in the condensers of the low-pressure turbines before being sent to the deaerators of the high-pressure units, but there is equipment through which some air may come in contact with the feedwater; such as leakage through the packing of the hotwell pump, etc., which necessitates the use of a deaerator. The deaeration of makeup water takes place in the condensers of the low-pressure units, and the makeup water comes over mixed with the condensate from the unit to which it was admitted.

Since the installation of the high-pressure units in Waterside, it has not been possible, due to load conditions, to cut out the low-pressure boilers. The supply of all make-up water needed in the station is fed to the low-pressure boilers, so that the high-pressure boilers have 100 per cent condensate. On several occasions an idle high-pressure boiler was filled too fast and thereby drained the deaerator to such a point that makeup had to be put into the deaerator from the city water connection, thus adding to the work imposed upon the deaerator, with a resulting decrease in the efficiency of the deaerator.

The following table gives the performance of the high-pressure units:

PERFORMANCE OF HIGH-PRESSURE INSTALLATION AT WATERSIDE STATION

	High-Pressure Turbine-generators	
	Unit No. 4	Unit No. 5
Date in commission	Sept. 10, 1937	June 29, 1938
Kilowatt-hours generated	325,909,000	258,260,000
Maximum kw load on generator	47,000	52,000
Service hours	11377.4	8250.6
Total available hours	12379.1	8980.3
Idle hours[a]	1001.7	729.7
Outage hours	4165.4	556.5
Period hours	16544.5	9536.8
Availability factor (ratio of available hours to period hours), per cent	74.8	94.2
Use factor (ratio of average load for service period to rated capacity), per cent	54.0	59.1
Capacity factor (ratio of average load for period to rated capacity), per cent	37.2	51.1

	High-Pressure Boilers			
	No. 4A boiler	No. 4B boiler	No. 5A boiler	No. 5B boiler
Date in Commission	Sept. 10, 1937	Sept. 10, 1937	June 29, 1938	July 25, 1938
Maximum steaming rate for 1 hr., lb	503,300	501,100	524,800	509,800
Service hours	9914.7	10546.8	6788.8	7292.6
Idle hours[a]	905.7	902.9	760.7	400.6
Total available hours	10,820.4	11,449.7	7,549.5	7,693.5
Outage hours	5724.1	5094.8	1987.3	1218.0
Period hours	16,544.5	16,544.5	9,536.8	8,911.5
Availability factor (ratio of available hours to period hours)	65.4	69.2	79.2	86.3

[a] Hours available but not in operation due to conflicting outage of dependent equipment.

Fisk Station Topping-Unit Operation

By A. E. GRUNERT

Superintendent of Generating Stations, Commonwealth Edison Company, Chicago

THE Fisk station high-pressure topping plant has completed nearly two years of operation. The first two months' operation have been previously outlined. That discussion was largely a disclosure of operating difficulties which invariably reveal themselves with initial operation of new developments of this nature and of defects in design which caused these difficulties.

In brief, the installation consists of a 30,000-kw, 1200-lb per sq in. 900-F turbine-generator, supplied with steam by two 375,000-lb per hr boilers. All auxiliaries are electrically driven except boiler feed pumps. Turbines for these three pumps take steam from the high-pressure header and exhaust to the low-pressure header in parallel with the topping turbine. The capacity of this topping installation was so chosen that the exhaust would supply the steam demand of two 25-cycle horizontal units. This combination forms in effect a flexible and efficient 90,000-kw cross-compound unit. Indicated production economy of the combined plant is approximately 12,800 Btu per net kwhr. Some reduction in this figure is anticipated when certain contemplated alterations in the low-pressure system are completed. The plant was originally designed for an actual performance of 12,500 Btu per kwhr and it is expected that this performance will eventually be attained.

Turbine-Generator Operation

The turbine-generator unit itself had an availability factor of 85.7 per cent for the three months' operation in 1937, 90.7 per cent for the year 1938 and 100 per cent for the first six months of 1939. During the 22-month period to August 1939 there were nine outage periods, with but three attributable to the turbine itself. The two longest were for general inspection and overhauling. During both of these periods repairs to spindle blading were necessary. The generator has had a perfect availability record.

Outage between October 8, and October 13, 1937, was necessary for adjustment of a throttle-valve bushing and for minor adjustment and tune-up of the governing gear. The next outage was caused by boiler carry-over deposits which caused the second inlet valve to stick. Heavy deposits of boiler carry-over were also found in the valves of the header system and these were removed by flushing the header with water. On July 2, 1938, outage was necessary when the first and second admission valves

were found to be sticking. Upon removal and inspection of the valves, the head of a $^3/_4$-in. cap screw was found lodged between the seat and disk of the second inlet valve. Upon inspection of the throttle valve it was found that this cap screw head had broken from one of the screws which held the throttle-valve seat to the throttle-valve body. The sticking of the first inlet valve was caused by valve-stem packing which had lost its plastic qualities and had caused excessive friction. A combination die-formed resilient-metal-ring and soft-asbestos-ring packing was substituted but lasted only three weeks.

The metal-foil packing rings disintegrated under high temperature and particles adhered to the valve stems. To ease the duty of the packing the leak-off was changed from 225 lb per sq in. to approximately 4 lb per sq in. Soft packing in die-formed rings was then installed and the number of rings was decreased to that required by the new pressure. This change proved satisfactory.

The inspection made at this time showed that the stellite seat facings were in perfect condition. Three broken $3^1/_4$-in. cylinder studs, which were judged to have failed due to defects in material or machining, were replaced in the bolting that is used for the turbine-cylinder joint. The turbine admission-valve-operating mechanism needed correction where clearances did not correspond to design dimensions. Lapped admission-valve-cover joints made up without gaskets held tight under high pressures and temperatures. Crane ring-type joints on all admission-inlet bends were found to be in good condition. The trip-gear mechanism, which on several occasions had operated sluggishly, was fitted with an Alemite lubricating system during this outage. This change has materially improved its operation.

The integral shrouds of the first moving row of impulse blades were originally welded together in groups of five. During inspection it was found that many of the welded joints had cracked, although the welding between several pairs of blades still remained sound. The strength of the original welding, however, had been somewhat reduced during manufacture in securing a smooth cylindrical surface by turning down the blade tips after welding. The blades of the first impulse row were rewelded in pairs during overhauling and a much heavier welding bead was used than in the original assembly. The full section of the welding bead was left in place for strength in this repair.

During March, April and May of 1939, however, the steam rate of the topping turbine showed gradual increase. This was particularly noticeable the first part of May when the steam rate had increased to a corrected rate of 26.9 lb per kwhr at 23,000-kw load. This was reflected in the division of load between the topping turbine and the low-pressure turbines to which steam was supplied. During the same period, a reduction of capacity had been experienced in the auxiliary turbines driving the boiler feed pumps. Fouling of nozzles and blading of these small turbines was suspected and successful washing restored their capacity. This experience led to the washing of the topping unit.

Analysis showed the blade fouling to consist of approximately 40 per cent soluble sodium silicate, 23 per cent sodium hydroxide and 23 per cent sodium chloride. Other soluble inorganic salts made up the remainder of the deposit.

After the washing period, the corrected steam rate of the topping turbine at a load of 27,000 kw, was found to be 24 lb per kwhr.

After a month of continuous operation subsequent to washing of the turbine, the topping plant was taken out of service for scheduled inspection on July 6, 1939. When the turbine was opened 26 blades in the second-spindle impulse row were found broken. The only evidence of this failure, noticeable while the unit was in operation, was an increased steam rate which had not returned fully to normal after completion of the washing procedure. Blade failure, however, was not definitely expected as the unit ran in balance before inspection.

Steam Generators

The two steam-generating units had an average availability factor of 61.2 per cent for 1937, 80.2 per cent for 1938 and 87.6 per cent for the first six months of 1939. Steam supply, however, has been available from one or both units during all except two short periods in the first four months of operation.

In the early operation of the boilers, joint leaks developed where recirculators entered headers of the side-wall screens and also where economizer tubes entered the steam drums. Rerolling failed to prevent the recurrence of leaks during further service, and it was necessary to seal-weld the joints for tightness. Inability to hold rolled economizer joints tight was attributed to strains due to variable economizer temperatures. Recurring leakage of rolled recirculator joints was attributed to excessive joint strains set up by unequal expansion of recirculators and screen-wall tubes. Seal-welding, where necessary, has prevented joint leakage but strains at the joints persist. These strains have to the present time caused no apparent difficulty other than the leakage before joints were seal-welded.

During the initial operation carry-over deposits were found in header valves and control valves of the turbine. Tests for steam purity, made when the units were steaming at 230,000 lb per hr, indicated that excessive carry-over was present when total solid concentrations in boiler water were maintained at 425 ppm. Lowering of the water level resulted in carry-over of less than 1 ppm at this rating but, when ratings were increased to 310,000 lb per hr, carry-over again became excessive. As 375,000 lb of steam per hr is required from each boiler for designed operation of the topping installation, improvements for better steam purity were necessary. With a changed drum baffle and steam-scrubber arrangement, satisfactory steam purity has been attained at normal boiler ratings when total solids in the boiler water were maintained at 400 ppm.

As ratings were increased, difficulties with furnace-slag accumulations on the sloping portion of the secondary furnace wall were experienced. The original design provided for operation of the secondary furnace as a dry-bottom furnace. This arrangement proved impractical as slag built up on the sloping secondary furnace rear wall in thicknesses of 4 to 12 in. and at times avalanched down in quantities and sizes so large that removal by the hydrojet system was impossible. During boiler outages in December 1937, the secondary furnace bottoms were changed so that all furnace slag is readily removed through the slag-drip holes of the primary furnace in liquid form.

Through this period difficulties were experienced with failures of vertical slag-screen tubes and ruptures of tubes around the slag-drip openings in the primary furnace floor. The changes made consisted first, of the addition of 12 recirculating tubes between the upper slag-screen header and the lower distribution header to the screen; second, of offsetting alternate groups of two slag-screen tubes into the secondary furnace instead of into the primary furnace as originally designed; and third, of moving the burners 2 ft 10 in. forward in the primary furnace. These changes had the effect of improving circulation and reducing the duty imposed on the tubes which previously had ruptured. A better balance in circulation between the screen-tube and floor-tube circuits also resulted. Further changes that were made to improve conditions in the floor-tube sections consisted of increasing the radius of tube bend in tubes around the slag-drip holes and the installation of water-cooling coils at these slag openings to retain a deeper protecting layer of molten slag over the floor tubes.

Difficulties with blistering and rupturing of tubes in the vertical slag screen, and in the primary furnace floor and upper generating-tube sections, had caused questioning of the adequacy of boiler-water circulation and of the water treatment used in the installation. Apparently some of the tube failures were aggravated by more or less loose deposits which had accumulated at the points of tube rupture. These deposits had settled out of suspension in such quantities as to be evidence of sluggish circulation. Water lines in the interiors of the top-row tubes in the generating section were also evidence of inadequate circulation. In an effort to improve this latter condition, the top row of generating tubes was replaced with a changed design of tubes during outages of No. 1 boiler early in July 1938, and of No. 2 boiler from August 27, to September 10, 1938. The original top tubes were parallel to the remainder of the tubes in the bank, while the new tubes were bent.

Soot-blower position changes were made during these boiler outages for more effective cleaning of the heating surface and the soot-blower-supply-header piping was changed to secure higher pressure at the blower heads for more effective cleaning.

Operation of the boilers from October 1938, to February 1939, was interrupted with several outages taken to clean tubes and make changes to improve circulation in the generating section. Restrictor plates in the uptake headers of this bank of tubes, altered design of top-row generating tubes and installation of tube cores in the upper ends of the top two rows of generating tubes were tried in efforts to prevent tube failures. These alterations failed to produce the desired result.

During the outage of No. 2 boiler between January 29, and February 6, and of No. 1 boiler between February 10, and February 17, 1939, distributor tubes made up of 1-in. tubing with a cone attached at the bottom were inserted in each of the uptake headers of the generating-tube section. The cone is arranged to divert the intense circulation of the bottom-row tubes through the 1-in. tube, while the 1-in. tube terminates near the top of the header and flow through it tends to induce circulation in the remaining tubes in the header. Sufficient equalization of circulation has been attained with this arrangement to prevent further tube failures in this section.

With the changes mentioned, both boilers have operated for three-month periods and were taken out of service during May 1939, only for inspection. No condition was found in these inspections which would have interfered with a longer service run on either boiler.

Conclusions

In general it appears that the tube failures experienced during these correction and development periods have been largely due, directly or indirectly, to sluggish circulation. While there are many factors in operation and design which may contribute to this condition, it would appear that the matter of solid-water downcomer supply is particularly important as is also the matter of ample return-circulating-tube area. It would also appear that where relatively high heat transfers occur, parallel circulation with unequal flow resistances should be avoided as far as practical design will permit. The several changes in these boiler units have largely been made with the intent to improve one or the other of these conditions. The records of improved availability indicate that efforts along these lines have been sufficiently successful to regard boiler-operating periods of six or more months duration as a reasonable expectancy. Turbine availability in this topping installation has exceeded this performance in previous operation. With the improvements now being effected, a very desirable plant-availability performance is anticipated.

Logan Station of Appalachian Electric Power Co.

By PHILIP SPORN, V.P. and Ch.Engr.,
American Gas and Electric Service Corp.

BEFORE beginning a review of the approximately two years of operating experience at the Logan Station, a brief description of the major equipment installed in 1937 will serve as a background. The superposed extension consists of a 40,000-kw, 3600-rpm, water- and hydrogen-cooled generator supplied with steam at 1250 lb per sq in. 925 F, from a single boiler of 1,000,000-lb per hr capacity and exhausting at 200 lb per sq in. 510 F to five low-pressure turbines totaling 50,400 kw.

Initial operation of the high-pressure boiler was started in October 1937, and trial operation of the turbine, November 2, 1937. Since the starting date until August 1939, the high-pressure section of the plant was available 57.3 per cent of the time, while the service hours were 56 per cent of the time. The capacity factor for this period was 40.8 per cent. The availability of the high-pressure turbine alone was 86.4 per cent and the service hours 56 per cent of the elapsed time. The single high-pressure boiler, which is used for the low-pressure section of the plant through the pressure-reducing and desuperheating system when not supplying the topping turbine, had service hours equal to availability amounting to 71.8 per cent of the period. Details of the outages on the high-pressure turbine and boiler will follow later.

Since July 1938, when the last major turbine difficulty was remedied, the availability of the high-pressure section of the plant has increased to 81.5 per cent, the service hours to 80.2 per cent, and the capacity factor to 61.8

per cent. For the turbine only the availability at 97.2 per cent and the service hours at 80.2 per cent have been quite satisfactory. The high-pressure-boiler performance is encouraging, with availability and service hours increasing to 84.7 per cent in this 13-month period. During this period, the station heat rate of 14,400 Btu per kwhr compares favorably with the design expectations, remembering of course that a serious shortage of circulating water in the summer months, necessitating spray nozzles and recirculation, is an uncontrollable influence on over-all plant economy.

Under favorable winter conditions, with ample circulating water, a gross station load of 103,000 kw has been attained, involving 48,500 kw on the 40,000-kw topping unit supplied with 1,000,000 lb per hr of steam from the single high-pressure boiler.

Starting and Stopping

Basically, the system of starting and stopping is one in which the low-pressure boilers, the low-pressure turbines, the high-pressure boiler and the topping turbine are treated as separate divisions, each of which is operated separately but in sequence. Whenever the high-pressure boiler is out of service at least two of the low-pressure boilers and two of the five low-pressure turbines are operated. The desired load on these units is maintained by backing down on the low-pressure boilers while steam flow is increased through the reducing valve as the high-pressure boiler is started and loaded. The high-pressure boiler could not be started without at least one of the low-pressure boilers in service because the induced-draft fans are turbine-driven.

Then the topping turbine is warmed through a manually operated atmospheric exhaust. When ready, the topping turbine under control of the speed governor is synchronized, then put under control of the back-pressure governor and loaded while flow through the reducing station decreases. The reverse order is followed when taking the high-pressure equipment off the line. Under running conditions, the reducing valves are closed, the load is varied on the low-pressure turbines which, in turn, controls the steam flow and load on the topping unit through the medium of the back-pressure regulator on the topping turbine.

High-Pressure Turbine-Generator

The major outages on the high-pressure turbine have resulted from failure on two occasions of the first-stage shroud band. With the second shroud-band failure, the turbine manufacturer gave proper consideration to the extreme combinations of stress to which the first-stage blading is subjected, involving intermittent stress from partial peripheral admission and stress from centrifugal force coupled with high-temperature effect. Since the second repair was completed and the turbine placed on the line on July 15, 1938, it is gratifying to be able to report that no further trouble has resulted to date from the first-stage shroud band.

Overheating of blades in the topping turbine, caused from motoring of its generator with insufficient steam flow, when low-pressure units have tripped out, is prevented at Logan by a somewhat special reverse-power relay which the author helped to develop.

The scheme consists of a sensitive reverse-power relay calibrated to operate on power component only and to close its contacts to trip the generator off the line in case the power flow is from the bus-bars into the generator with a magnitude of $^1/_2$ per cent of the kilowatt-rating of the generator after a time of 1 min. In addition to this reverse-power relay, a timing relay is provided to give the desired time of 1 min. A single current transformer is employed with a ratio of approximately full-load rating of the generator to give secondary current. Furthermore, a lockout single-phase reverse-power relay is provided to make the above sensitive reverse power relay inoperative, provided the generator is supplying power to the bus-bars of an amount equal to or greater than 40 per cent of its kilowatt-rating. The installation of this lockout relay is provided to insure that the generator will not trip off the line unnecessarily due to improper operation of the sensitive reverse-power relay on surges or otherwise. In addition, an alarm circuit is provided to operate at the instant the generator starts motoring, so as to inform the operator that the generator is motoring and permit him to correct conditions within the period of 1 min before tripping occurs, if possible.

During the past year there have been two occasions when the low-pressure units have tripped out from failure of the group excitation for these units. On both occasions the high-pressure unit was prevented from motoring by the successful functioning of the special reverse-power relay.

The hydrogen-cooled generator has functioned most gratifyingly even under capacity load with the adverse condition of high cooling-water temperature. Although this generator is designed for a gas pressure of 15 lb per sq in. and has had test runs at this pressure, during which the shaft-sealing and gas consumption were satisfactory and lower temperature of windings realized, day-by-day operation has been confined to a pressure of 0.5 lb per sq in. Even with cooling water at 90 F, a higher gas pressure was not needed to effect proper cooling of the windings. Hydrogen purity is easily maintained at 99 to 100 per cent, and gas consumption, averaging less than 40 cu ft per day, has been costing less than $300 per year.

High-Pressure Boiler

The 1,000,000-lb per hr, dry-bottom, pulverized-fuel boiler has been subject to some outage. Ash-screen tube failures resulting from impaired circulation and excessive heat input required replacement. To remedy this difficulty, smaller diameter tubes having spiral circulating strips and an increased slope were substituted and burner angles adjusted with satisfactory results.

West Virginia bituminous coal from four different seams near Logan with ash-fusion temperatures ranging from 2350 to 2700 F has been burned without difficulty. Slagging has not been serious and cleaning of boiler tubes by soot blowers and lancing has been easily accomplished. Load swings of 10,000 to 15,000 lb per hr are readily handled and, on occasions, it has been possible to drop load from 900,000 to 540,000 lb per hr momentarily. Steam temperature has been controllable within the prescribed range with the remotely operated bypass dampers. With tangential firing, a minimum boiler load of 300,000 lb per hr can be attained without loss of flame stability. However, it is interesting to note that, with a fuel combination of gas and coal, a load of 175,000 lb per hr has been carried successfully for a 2-hour period.

Four auxiliary natural-gas burners are used for starting with the aid of a kerosene torch and together are capable of carrying a boiler load of 50,000 lb per hr.

Mills and Air Heaters

The four Hardinge mills each of 15 tons per hr capacity have been rendering satisfactory service with a power input of 16 kw each at full capacity. Experience indicates that exhauster blades made of boiler plate require replacement after a mill has handled 35,000 tons, and the wear on the ball charge amounts to 0.086 lb per ton of coal. The two Ljungstrom air heaters when cleaned once each shift with steam soot blowers have maintained their capacity and exhibited no tendency to fouling. However, the exit flue-gas temperature, leaving the air heaters, remains about 30 or 40 F higher than the manufacturer's performance guarantee.

Feedwater

Feedwater makeup is supplied from an evaporator whose feed is coagulated river water in which temporary hardness usually predominates, forming a scale in the evaporator not readily susceptible to cracking. To offset this, approximately 0.2 ppm of tannin is added to the evaporator feed for 1 ppm of hardness. Total dissolved solids in the vapor leaving the evaporator is confined to 2 ppm or less. A pressure-type deaerator located midway in the feedwater-heating circuit, using exhaust steam from the turbine-driven induced-draft fans, has consistently maintained the dissolved oxygen of the feedwater at 0.005 cc per l or less. Scavenging of final oxygen is obtained by continuous feeding of ferrous sulphate and caustic soda at the deaerator outlet in proportion to the dissolved oxygen in the feedwater. Orthophosphates and caustic are fed in shots into the feedwater at the discharge side of the regulator for maintaining a pH value of 9.6 and a phosphate concentration of 10 to 25 ppm as PO_4.

Boiler Feed Pumps

Three identical 3600-rpm feed pumps are installed, one of which is motor-driven and two turbine-driven with the exhaust steam absorbed in the feedwater-heating cycle. Ordinarily, the turbine-driven pumps are used with the motor-driven pump as standby. These pumps have horizontally split cases and handle water at 350 to 390 F. Their performance has been satisfactory in every way except for failure of ring gaskets involved with the removable head at the discharge end of the pump where the balancing disks are located.

Heaters

In the feedwater-heating cycle, there are no heaters on the discharge side of the boiler feed pumps. Following the deaerator on the suction side of the feed pumps are two vertical surface heaters of the floating-head type both handling water at 450 lb per sq in. and using steam at 100 and 200 lb per sq in., respectively. Admiralty tubes in the 100-lb heater and arsenical copper tubes in the 200-lb heater have both functioned satisfactorily thus far without leakage or tube dirtiness. After some experience with various head gaskets, the toroidal type was definitely unsatisfactory, but copper and corrugated monel have proved to be much superior.

Conclusion

As a general conclusion it may be said that the selection of 1250 lb pressure, 925 F temperature for a topping extension to this station and the equipment designed for use therewith have proved a design, operating and financial success. If we had the job to do over again, the experience gained of course would enable improvement in many details, but basically the design would be the same.

Omaha Station of Nebraska Power Company

By LOUIS ELLIOTT

Consulting Mechanical Engineer, Ebasco Services, Inc.

THE present statement covers the period from initial operation in February 1937, to May 1939, and includes operating data and experience in addition to or differing from that detailed in the previous paper.

In brief, the extension includes one 10,000-kw 0.8-power factor turbine-generator, designed for 1200-lb, 900-F operation and one 265,000-lb per hr bent-tube boiler with economizer and regenerative airheater, fired by a 570-sq ft traveling-grate stoker. The high-pressure turbine is superposed on a 15,000-kw 200-lb condensing unit, with a non-automatic reducing- and -desuperheating station discharging to a 325-lb header. The division of load between the high-pressure and topped units is determined by maintenance of constant back pressure on the former. The station is operated normally with at least one 325-lb turbine and one or more boilers on the line, in addition to the superposed combination.

Availability (practically equal to "demand availability") of the high-pressure-turbine unit for the entire period has been 82 per cent, and for the last 7300 hr, since latest overhaul, 94 per cent. High-pressure boiler availability has been 87 per cent for the entire period, and 94 per cent since the latest general overhaul. Generation by the high-pressure unit has been at 78 per cent unit-output factor (based on 10,000-kw rating) for the entire service period. The operation of the topping combination has been practically continuous since the early part of this year, and reliability is considered as substantially on a par with that of the 325-lb section of the plant.

High-Pressure Turbine

Reduction of turbine capacity from blade deposits was experienced prior to the February 1938, overhaul, at which time the blading was cleaned by blasting with fly ash because silica content and temperature conditions prevented removal by washing. Subsequently, boiler-water concentrations were reduced, and leakage of the low-pressure unit condenser is now checked regularly. Stage-pressures and load tests now indicate no appreciable scaling of blading.

As at first installed, the turbine water rate was 2 to 3 per cent high at lighter loads, caused in part by excessive high-pressure packing clearances, but largely by turbulence of steam in the space between the first-stage-wheel exit and smaller diameter nozzles of the second stage. A dam or baffle was installed in the first-stage

shell space, extending from the inside of the shell to the rotor and attached to the second-stage diaphragm and to the inside of the upper half of the casing. The improvement effected eliminated much of the loss and permitted the turbine to meet its expected performance.

Starting-up procedure has been modified as compared with the method reported two years ago. The 200-lb turbine is now started first, taking steam through the 325–200-lb reducing valve. The exhaust valve of the high-pressure turbine is also opened to admit 200-lb steam to the turbine casing. The high-pressure boiler is brought up to 600 or 800 lb pressure, passing 75,000 to 100,000 lb of steam per hr through the 1200–325-lb reducing valve. The high-pressure turbine is then started, exhausting to the 200-lb turbine. As the load is picked up, the 1200–325-lb reducing valve is closed, and the boiler pressure is raised to 1200 lb.

This method obviates the loss of steam to the atmosphere, inherent in the original starting method. Starts and stops have been relatively infrequent and only as have been occasioned by the maintenance requirements.

High-Pressure Boiler

Deficiency in total steam temperature persists, correction having been delayed. On account of this temperature condition, there has been no need for control of steam temperature, for which a manually operated bypass gas damper is provided.

The Kansas coal burned has relatively high sulphur content and low ash-softening temperature; samples show initial deformation at 1850 F and a fluid condition at 2100 F or below. Because of these ash characteristics, difficulties of cleaning boiler and air heater surfaces increase rapidly as maximum boiler capacity is approached. The boiler is now normally operated during the day period at an output of approximately 225,000 lb per hr, as slagging difficulties increase above 230,000- to 240,-000-lb per hr output. It requires 14 man-hours per day for cleaning of the heat-transfer surfaces. No circulation troubles have been experienced in boiler or furnace walls or arches, and the traveling-grate stoker has developed no operating or maintenance difficulties notwithstanding its great size.

Boiler water is conditioned to maintain an average pH value of 10.7, while keeping total solids at 250 ppm and total alkalinity at 75 to 100 ppm. A ratio of 0.5 between sulphates and carbonates is normal.

Corrosion and plugging of the air heater at the top of the inlet side of the rotating element results from the sulphur and moisture content of the coal and necessitated a bypass around the air heater to permit cleaning.

Discussion

In the discussion, reports were given on three other installations whose preliminary operations were covered two years ago. These were Springdale and Rivesville Stations of the West Penn Power Company, reported by James Muir, and the Millers Ford Station, reported by C. H. Spiehler. In addition, S. B. Flagg discussed the earlier topping installation of the Houston Lighting & Power Company; C. C. Baltzly, of the Philadelphia Electric Company, reviewed operation of the more recent high-pressure units at Schuylkill Station; and F. P. Fairchild reported on 17 months' operation of the topping installation at Essex Station of the Public Service Electric & Gas Co. of N. J.

At Springdale a 400-deg spread between the softening and the fluid temperatures of the ash had caused slag accumulations on the walls of the secondary furnace and seriously reduced the heat absorption. This led to the replacement of block-covered walls with bare walls. At Rivesville, however, a lower fusing temperature of the ash rendered such a change unnecessary. At the former station faulty circulation was responsible for some tube failures, leaks at superheater joints were corrected by welding and excessive carryover was overcome by the installation of cyclone steam washers. Impulse turbine blading failures were also encountered at Springdale and the unit is now operating without the impulse stage. However, the difficulties either have been or are in the process of being corrected; Rivesville has been operating satisfactorily since October 1938 and the high-pressure units at Springdale now have an availability of from 82 to 85 per cent.

At Millers Ford Station the availability of the high-pressure boilers to date has been 76.1 and 72.87 per cent, respectively, and would have been higher except for outages due to factors not attributable to the boilers. Some tube corrosion was encountered; there were some first-stage turbine-blading failures and heavy deposits in the lower stages from carryover; all of which have now been overcome and the turbine availability for the past two years has been 92.3 per cent. The mills have handled over 80,000 tons of coal without renewal of the balls and the power consumption for pulverizing has been from 18 to18.5 kwhr per ton. Superposition has reduced the station heat rate from 20,000 to 15,075 Btu per kwhr.

The high-pressure boilers at Schuylkill Station operated 87 per cent of the time for the first year. Some initial troubles were encountered in the oil burners for starting the pulverized coal fires but these have now been corrected. Failures of one floor tube, one wall tube and one tube leading to the drum were reported and some alterations in the burner boxes have been necessary. The bowl mills have operated very satisfactorily with a power consumption of about 8 kwhr per ton. The high-pressure turbine has been operating without the impulse blading and rubbing necessitated return of the spindle to the manufacturer. The turbine-generator is now operating with hydrogen cooling and its performance has exceeded the guarantee by about 2 per cent.

Seventeen months' operation at Essex Station has shown availabilities of 82 and 88 per cent for the two high-pressure boilers and 92 per cent for the turbine-generator. The boilers have been operated alternately on pulverized coal and oil for periods of six to seven months. Initially it was possible to carry only two-thirds load without excessive carryover. This was corrected by the installation of cyclone separators, which also improved the circulation and a boiler water concentration of 600 ppm is now carried regularly with 1 ppm in the steam. The soot blower arrangement was altered to facilitate cleaning the superheater and prevent arching of the slag. A steam pressure of 450 lb is employed for blowing the superheater tubes and 225 lb for the walls.

J. C. Hobbs told briefly of the 2200-lb pressure installation at the Diamond Alkali Co., Painesville, Ohio, which has now been in operation two months. This 300,000-lb per hr boiler operates with natural circulation and consists only of water walls, drum, superheater and economizer.

Method of HEAT TRANSFER Through Insulation

By F. PEITER and Dr. M. J. FISH
Combustion Engineering Company, Inc.

In COMBUSTION of May 1938 the authors presented a method of computing temperatures and heat flow through vertical wall insulation, but the properties of matter which make one substance a better insulator than another were not discussed. The present article submits a viewpoint of the mechanics of insulation which represents a departure from the commonly accepted notions on the subject.

THE heat transfer coefficient of a uniform material is defined as the time rate of heat flow per unit area per unit of temperature difference and is commonly called the "thermal conductivity." Its reciprocal is a measure of the resistance to heat flow and can be used to determine the insulating value of a substance. The heat transfer coefficient of a material is measured only after a steady state or equilibrium of test conditions has been reached and depends on the temperature, although it is not a function of the area, shape and surface resistances. The usual methods of measurement eliminate the effect of surface radiation and surface convection.

The ordinary conception of the insulating values of various materials has come from the statement that a vacuum is the best insulator and that an air space which contains motionless air is almost as good as the vacuum.[1] Starting with these statements, the study of heat flow has proceeded along the lines that the insulating value of a material depends upon the proportion of entrapped air in the material and that the larger the percentage of voids, the greater is the efficiency of the material as an insulator. This method is distinguished by generality, and by its use one obtains no deep insight into the concrete mechanism of the process of heat transfer. Therefore, many problems cannot be understood completely.

A consideration of the laws of heat flow will show that the foregoing hypothesis does not present a true picture of what actually takes place. The heat energy is transmitted through the insulating material by conduction, convection and radiation.

In the flow of heat through a solid homogeneous body by conduction, the accepted theory is that the increase of temperature increases the motion of the molecules and that they vibrate about a mean fixed position. The increase in temperature is transmitted from one molecule to another. The amount of heat transferred through homogeneous solids is given by the following expression:

$$Q = \frac{\alpha A (T_2 - T_1)}{L} \qquad (1)$$

where Q = Btu per hr
α = coefficient of conductivity which depends upon the temperature and is given in Btu per hr per sq ft per deg F per inch of thickness
A = area in sq ft
$T_2 - T_1$ = temperature difference in deg F
L = length of path of heat transfer in inches

For solid metals and some solid non-metals such as glass and stone, the heat transfer is by conduction only. In general, their coefficients of heat transfer are too large for them to be used as insulators. Most insulating materials are either of fibrous character, such as rock wool and glass wool, or are of a porous nature. An example of the latter would be an insulating brick which has been made by mixing a finely granulated volatile organic chemical, such as napthalene, with the plastic clay mixture used to manufacture the ordinary firebrick. When the resulting mixture is baked in the kiln, the organic chemical volatilizes so that the insulating brick is porous and full of voids. Now the heat flow by conduction through such an insulating brick, where the percentage of voids is large, proceeds through the solid portion of the brick and also through the gas film of the small voids. The path through the solid portion of the material is tortuous and much longer than if the voids were not present.

As can be seen by an examination of equation (1), if the temperatures of both the hot and the cold surfaces are maintained constant, the heat flow by conduction through the solid portion decreases with the increased value of L. The flow of heat by conduction through the gases is also decreased by an increase of the voids (if the temperatures are again constant) since the transfer of heat by conduction through gases is relatively small. In the case of fibrous materials, each fiber is usually surrounded by an air film and contiguous fibers are in poor contact due to their shapes. Then the path of heat flow through the solid portion is not continuous but presents a tremendously large number of interruptions.

Of course, the temperatures are not maintained constant in the actual use of the insulators, but with given values of T_2 and the ambient air temperature, both Q and T_1 will change for different materials of the same thickness.

[1] "Refractory Materials" by Alfred B. Searle, page 327, 2nd ed. 1924, Charles Griffin & Co., Ltd.

The flow of heat by convection due to the motion of warm gases (or liquids) takes place because of the difference in density of the gases when the temperature changes. An important notion in the transfer of heat by convection is that of the film which is adjacent to a solid. This film or "boundary layer" is a layer of gas which adheres to the solid surface. The particles which are in actual contact with the surface are at rest while those farther away move relative to the surface with a velocity increasing with their distance from the surface. Through this film, the heat is transmitted mostly by conduction and if the thickness of film were known, it might be possible to calculate the heat transfer by conductance through this layer. The film does not move unless torn away by rapid flow and since gases are not good conductors of heat, there is a large temperature decrease through the film. The heat transfer by convection depends upon the viscosity of the gas, its velocity, the shape of the vessel and other factors.

From this it can be seen that there is actually no such thing as a space where the air is motionless during heat flow. When the voids become very small, the flow of heat due to air motion in one of the voids is negligible and the term "dead air space" is often applied to the structure of the material.

Thermal radiation is assumed to be produced by the agitation of the atoms or molecules of a substance and may be regarded as a form of electromagnetic wave motion. In general, radiation, directed against a surface, is partly absorbed, partly reflected, and unless the body be very thick or opaque, partly transmitted. In a hollow heated enclosure, radiation is streaming back and forth in all possible directions. In nature, there is no material which absorbs all the radiation incident to it. Some materials, such as lampblack, reflect only a small fraction of the incident radiation and are commonly called "black." In scientific parlance, a perfect black body is defined as one whose surface absorbs all the radiant energy incident upon it. The rate at which a body emits radiation depends upon its temperature and the nature of its surface. Since both the hotter body and the receiving body are emitting radiation, the difference between the two is of interest.

The Stefan-Boltzmann law shows that the heat radiation between two bodies of different temperatures is

$$Q = k\left[\left(\frac{T_2}{100}\right)^4 - \left(\frac{T_1}{100}\right)^4\right] \qquad (2)$$

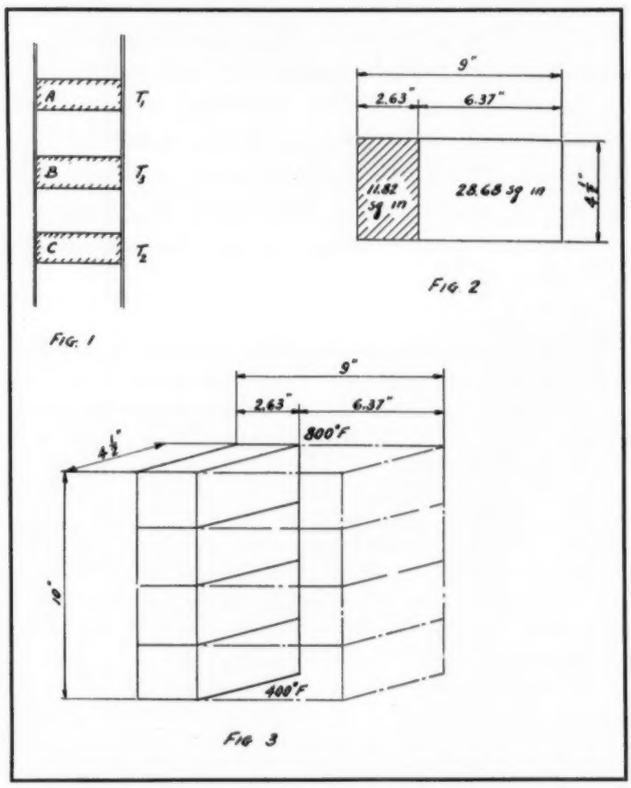
where Q = Btu per sq ft per hr
T_2 = temperature of the hot surface in deg F abs.
T_1 = temperature of the cold surface in deg F abs.
k = the constant of radiation, which depends upon the radiating power of the body as compared to the radiating power of a black body. For ideal black-body conditions, its value is 0.172 while it ranges from 0.155 for rough iron or brick surfaces, and about 0.13 for glazed brick surfaces, to 0.04 for smooth metallic surfaces.[2]

The amount of thermal radiation increases tremendously with an increase in the value of T_2. The larger the value of T_2, the poorer insulator a vacuum becomes. This phenomenon explains the reason that a commercial thermos bottle will keep cold liquids cool for about 72 hours while hot liquids stay hot only about 24 hours. From this it can be seen that *a vacuum does not offer resistance to the flow of heat by radiation.*

In Fig. 1, if the two similar bodies A and C are in a hollow enclosure and maintained at the absolute temperatures T_1 and T_2, respectively, then the net heat energy radiated from A to C is

$$Q_1 = k\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$$

If, now, the body B which is similar to A and C is inserted in the enclosure and comes to equilibrium at the absolute temperature T_3, the net heat radiated from A



to B equals the amount of heat radiated from B to C. In this connection, it should be noted that the emissivity and absorptivity of a body are equal for radiation of the same wave lengths. Therefore,

$$Q_2 = \frac{k}{100^4}(T_1^4 - T_3^4) = \frac{k}{100^4}(T_3^4 - T_2^4)$$

or $$T_3^4 = \frac{T_1^4 + T_2^4}{2}$$

If this latter value is substituted in the first of the two values for Q_2 then

$$Q_2 = \frac{k}{2}\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$$

A comparison of this value with that of Q_1 shows that the introduction of the body B has decreased the heat flow by radiation to half its former value. When the number of interruptions is large, the resistance to the

[2] "Industrial Furnaces" by W. Trinks, page 23, vol. 1, 3rd ed. 1934, John Wiley & Sons, Inc.

transfer of heat by radiation becomes increasingly effective.

At this point, mention should be made of a class of insulating materials, of which aluminum foil is an example, which depend upon the ability of their shiny surfaces to reflect radiation.

To study the effect of innumerable small voids in the insulating material, consider an ordinary clay firebrick

Fig. 4—Microscopic view of infusorial earth

with dimensions $9 \times 4^1/_2 \times 2^1/_2$ in. whose weight is 7.5 lb, and the insulating brick which was previously mentioned as made by volatilization of an organic chemical so that the porous clay firebrick remains. This latter brick has the same dimensions as the ordinary firebrick but weighs only 2.19 lb.

The ordinary firebrick contains 40.5 sq in. or 0.281 sq ft in the $9 \times 4^1/_2$-in. cross-section, while the clay in the insulating brick can be compressed into the cross-hatched area of Fig. 2. This area is

$$\frac{2.19}{7.15} \times 40.5 = 11.82 \text{ sq in. or } 0.082 \text{ sq ft}$$

where the 9-in. length is cut to

$$\frac{2.19}{7.5} \times 9 = 2.63 \text{ in.}$$

The remaining area of $40.5 - 11.82 = 28.68$ sq in. in the length 6.37 in. represents the voids contained in the insulating brick.

The wall shown in Fig. 3, with hot-side temperature 800 F, that of the cool side 400 F, and the mean temperature 600 F, is made from fireclay bricks where each brick has the same amount of fireclay as has the insulating brick. Since the coefficient of conductivity at this mean temperature is $\alpha = 7$, the heat flow

$$Q_1 = \frac{0.082 \times 7 \times 400}{10} = 23 \text{ Btu per hr}$$

The insulating brick has a coefficient of conductivity equal to 0.98 and for an equal amount of fireclay its heat flow would be

$$Q_2 = \frac{0.281 \times 0.98 \times 400}{10} = 11 \text{ Btu per hr}$$

where the equivalent cross-section is taken as the full $9 \times 4^1/_2$-in. face.

In the foregoing, the transfer of heat through the brick by convection and radiation has been considered negligible in accordance with the previous statements on these methods of heat flow. Therefore, it would seem that the difference in the conductivity values and the heat flow between the fireclay and insulating bricks is due to the transfer of energy by conduction taking a longer path on account of the tortuous path of the internal structure of the insulating brick.

Other combustible materials such as sawdust and cork are mixed with the fireclay to obtain these lightweight, porous insulating bricks. Cork is used more extensively than is the sawdust because it gives a more uniform product. The combustible matter is burned out in the kiln and then the brick must be machined for accurate dimensions since the volatile products of combustion have caused the fireclay to attenuate and the brick to increase in volume.

Another insulating product which is known as a "block" commercially comes within the class of discrete substances. These are made by mixing materials of low insulating value together with a binder such as bentonite clay. The blocks are pressed in shape while wet and then dried in the furnace where the temperature

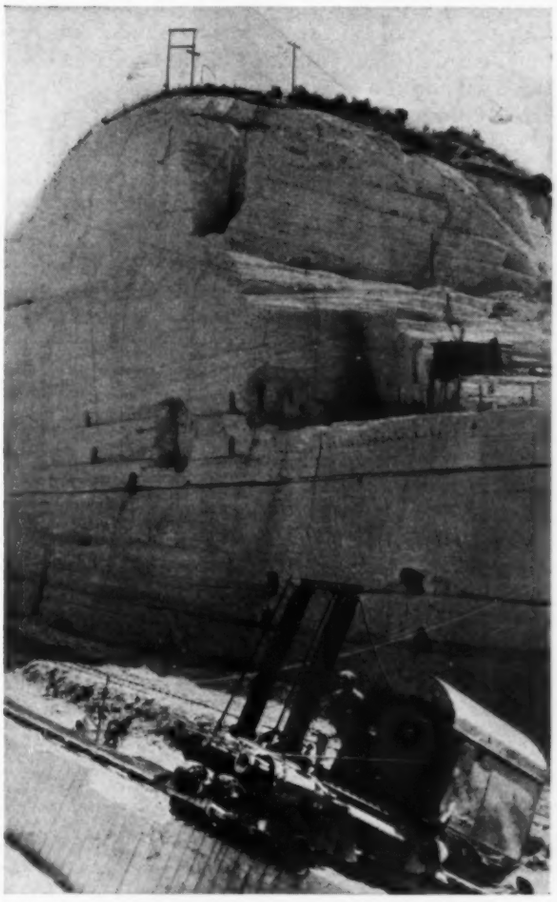


Fig. 5—Diatomaceous earth quarry
(Quarry of Celite Product Co., Lompoc, Calif.)

is a bit higher than that of boiling water. The important difference between these blocks and the insulating bricks mentioned above is that the former have not been subjected to temperatures high enough to give a chemical bond and when used should not be subjected to temperatures which will do so.

An interesting insulating material is diatomaceous or infusorial earth which is often known as kieselguhr. This earth is found as huge deposits (sometimes miles in extent and up to one hundred and fifty feet in depth) of the microscopic siliceous shells of diatoms which are extremely small unicellular plants. Some of these deposits contain as many as 40,000,000,000 shells to the cubic inch. Fig. 4 shows a microscopic view of infusorial earth in the Richmond, Virginia, deposit while Fig. 5 is a photograph of a diatomaceous earth quarry in California where insulating bricks are sawed out of the deposit.

Infusorial earth or kieselguhr occurs in beds which are sometimes 95 per cent or more of silica. It is very light and porous and as can be easily seen from Fig. 4 contains multitudes of small voids and interruptions thus making it an excellent material for resisting the transfer of heat.

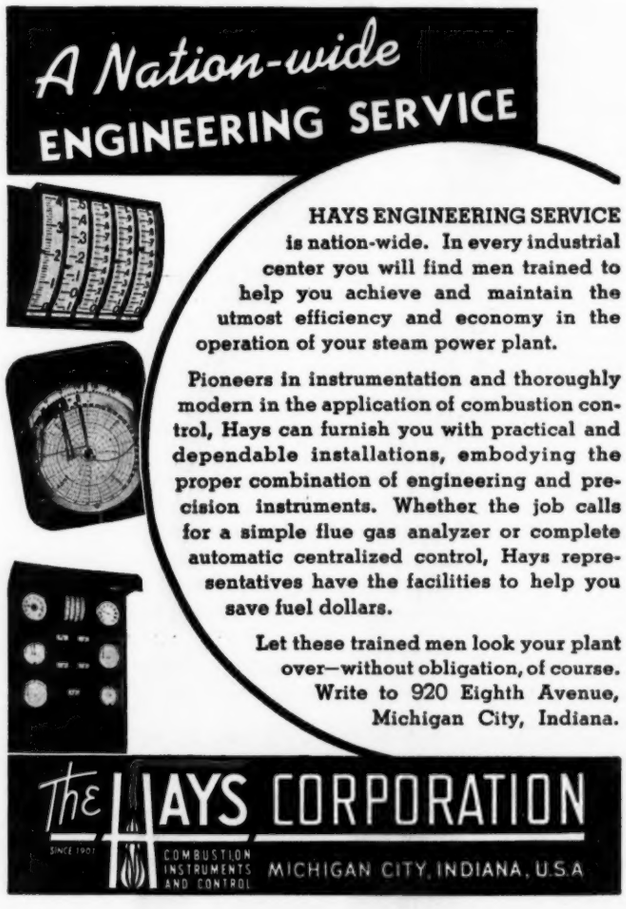
Engineering Truisms

As a commentary on engineering literature a reader has sent us a copy of the preface to the first edition of Trautwine's "Civil Engineers' Pocket-Book," which was first published in 1876. Because of the prestige achieved by the book and the truisms in the author's observations we are reproducing the following excerpts from the preface:

> Should experts in engineering complain that they do not find anything of interest in this volume, the writer would merely remind them that it was not his intention that they should. The book has been prepared for *young* members of the profession; and one of the leading objects has been to elucidate, in plain English, a few important elementary principles which the savants have enveloped in such a haze of mystery as to render pursuit hopeless to any but a confirmed mathematician.
>
> Comparatively few engineers are good mathematicians; and in the writer's opinion, it is fortunate that such is the case; for nature rarely combines high mathematical talent, with that practical tact, and observation of outward things, so essential to a successful engineer.
>
> There have been, it is true, brilliant exceptions; but they are very rare. But few even of those who have been tolerable mathematicians when young, can, as they advance in years and become engaged in business, spare the time necessary for retaining such accomplishments.
>
> Nearly all the scientific principles which constitute the foundation of civil engineering are susceptible of complete and satisfactory explanation to any person who *really* possesses only so much elementary knowledge of arithmetic and natural philosophy as is *supposed* to be taught to boys of twelve or fourteen in our public schools.*
>
> The little that is beyond this, might be safely intrusted to the savants. Let them work out the results, and give them to the engineer *in intelligible language*. We could afford to take their words for it, because such things are their specialty; and because we know that they are the best qualified to investigate them.
>
> The writer is frequently asked to name good elementary books on civil engineering; but regrets to say that there are very few such in our language. "Civil Engineering," by Professor Mahan of West Point; "Roads and Railroads," by the late Professor Gillespie; and the "Manual for Railroad Engineers," by George L. Vose, C.E., and Professor of Civil Engineering in Bowdoin College, Brunswick, Maine, are the best.
>
> The writer does not include Rankine, Moseley and Weisbach, because, although their books are the productions of masterminds, and exhibit a profundity of knowledge beyond the reach of ordinary men, yet their language also is so profound that very few engineers can read them. The writer himself, having long since forgotten the little higher mathematics he once knew, cannot. To him they are but little more than striking instances of how completely the most simple facts may be buried out of sight under heaps of mathematical rubbish.
>
> Philadelphia, September, 1876 — JOHN C. TRAUTWINE.

* Let two little boys weigh each other on a platform scale. Then when they balance each other on their board see-saw, let them see (and measure for themselves) that the lighter one is farther from the fence-rail on which their board is placed, in the same proportion as the heavier boy outweighs the lighter one. They will then have learned the grand principle of the *lever*. Then let them measure and see that the light one see-saws farther than the heavy one, in the same proportion; and they will have acquired the principle of *virtual velocities*. Explain to them that *equality of moments* means nothing more than that when they seat themselves at their measured distances on their see-saw, *they balance each other*. Let them see that the weight of the heavy boy, when multiplied by his distance in feet from the fence-rail amounts to just as much as the weight of the light one when multiplied by his distance, and that each of these amounts is in *fool-pounds*. Explain to them that the lighter boy, because he swings faster than the other, has greater *kinetic energy*, notwithstanding his lighter weight, and will therefore bump harder against the ground. The boys may then go to dinner, and probably puzzle their big lout of a brother who has just passed through college with high honors. They will not forget what they have learned, for they learned it *as play*, without any ear-pulling, spanking, or keeping in. Let their bats and balls, their marbles, their swings, etc., once become their philosophical apparatus, and children may be taught (*really* taught) many of the most important principles of engineering before they can read or write.

It is the ignorance of these principles, so easily taught even to children, that constitutes what is popularly called, "The practical engineer"; which, in the great majority of cases, means simply an ignoramus, who blunders along without knowing any other reason for what he does, than that he has seen it done so before. And it is this same ignorance that causes employers to prefer this practical man to one who is conversant with principles. They, themselves, were spanked, kept in, etc., when boys, because they could not master leverage, equality of moments, and virtual velocities, enveloped in x's p's, Greek letters, square-roots, cube-roots, etc., and they naturally set down any man as a fool who could. They turn up their noses at science, not dreaming that the word means simply, *knowing why*. And it must be confessed that they are not altogether without reason; for the savants appear to prepare their books with the express object of preventing purchasers (they have but few *readers*) from learning why.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COAL and GAS*

By A. M. BEEBEE
Gen. Supt. Gas Dept.
Rochester Gas and Electric Corp.

A review of our fuel resources in which the economic utilization of energy from coal, oil and gas is discussed. The effect of present and proposed hydroelectric projects on the unemployment problem is analyzed and the conclusion is reached that further development of uses for coal will promote a sound social order.

RESERVES of coal in this country are tremendous while those of oil and natural gas are definitely limited. The total known oil reserves at the present rates of use are estimated to last some fourteen or fifteen years. The more obviously favorable geological conditions have been picked and deeper and deeper drilling has been carried out, so that the cellar of sedimentary rocks has been approached. The organisms responsible for these oil and gas deposits existed in prehistoric seas and therefore these fuels are found only in rocks which are the result of sedimentation. When we approach rocks of the "Precambrian period," which are the result of igneous or molten conditions, all forms of life, even if it ever existed, were obliterated. Furthermore, the deeper drilling, in general, involves denser rocks, so that the essential pore space, necessary for commercially adequate reservoir rocks, tends to be lacking, as well as involving more expensive recovery costs. Therefore, the popular impression, as time goes on, that we merely drill deeper and get more oil has a very definite limit. This is important, because oil now supplies some 30 per cent of our total energy requirements.

Natural gas is in a relatively similar situation. This is especially true in the Appalachian fields east of the Mississippi. The mid-continent and California fields, however, are vast, so that total known reserves in this country will last, under present rates of withdrawal, from 20 to 25 years. But gas is a bulky substance. For natural gas fields to be commercially successful, a well must drain reservoir rocks of ten times the capacity of that necessary for a commercial oil well. The locations of reservoir rocks of such porosity and thickness and of adequate permeability are few and far between, though gas, by reason of its greater migrating power, tends to offset this great handicap. Natural gas we find now supplies 9.8 per cent of the nation's energy requirements.

Bituminous coal, on the other hand, up to a decade ago, supplied some 60 per cent of our energy requirements though, due to the increased development of natural gas, oil and water power, it now supplies but 45 per cent of our energy requirements. Yet we find this country has a coal reserve which, at present rates of use, will last over 4000 years; and, if used at a rate to supply nearly all our requirements, it will last some 2000 years.

Few realize that the energy in a pound of coal is some four to five times that in a pound of T.N.T., and that a ton of water must fall a mile to develop the energy-equivalent of a pound of coal. When all conversion efficiencies are considered, it must fall one-fourth mile to produce in electrical form the energy that can be generated from a pound of coal. It is interesting to note that the entire flow of the Niagara River, over the great Niagara Falls, is equivalent to an imaginary coal stream flowing at a rate only slightly faster than a walk in a pipe line 18 in. in diameter.

Coal Will Continue to Predominate

From the foregoing we cannot help but conclude that coal is the source of energy of the future in this country and that, as time develops, the tendency of oil and natural gas to crowd out coal will reverse itself in the very near future. This will be especially so as the ability to withdraw the oil from the sands becomes more and more difficult, due to the initial "head" of the fields being constantly reduced, and resort to pumping and pressure driving becomes necessary to produce the oil. This condition invariably results as fields become older.

Coal can be transported with a thermal loss of but a fraction of a per cent, while in the form of electricity the transmission losses run from 10 to 17 per cent. With gas the energy losses, including pumping requirements, are of the order of a very few per cent. Furthermore, recent studies[1] show convincingly that energy can be transported from 4 to 10 times as far in the form of coal on the railroads for the same cost as electrical energy transmitted by high voltage. This fact, plus the limited condensing-water facilities available at mine-mouth locations, has blasted the popular fallacy of a decade ago of mine-mouth electric generation and high-voltage transmission to market. In this connection it is interesting to read, on page 267 of the 1937 Report of the National Resource Committee on Technological Trends, the following:

"Furthermore, mine-mouth location will ordinarily involve electric transmission costs greater than freight charges on fuel, and at the same time long distance transmission lines reduce reliability of service."

* Excerpts from paper before A.S.M.E.-A.I.M.E. Joint Fuels Meeting at Columbus, Ohio, October 5 to 7, 1939.

[1] See "Economics of Subsidized Power" by Frank F. Fowle, COMBUSTION, March 1938.

While it is true that energy in the form of gas can be transported in pipe lines at costs that more closely approach the costs of freight on coal for equivalent energy, nevertheless, mine-mouth operation of gas plants will not be economical since the resultant by-products, such as coke and other materials, must be transported to market, and these latter might just as well ride along with the coal in the first place, with the resultant saving.

Energy in the form of fuels can be converted into useful heat with a high degree of efficiency, even when including the conversion losses from coal to gas. However, where the energy in fuels is converted into energy able to do work, i.e., electricity or mechanical energy, large losses of the order of 75 per cent are involved, whether the conversion is made by gas engine, boiler and turbine or any other known means of conversion. To take such energy which has experienced heavy losses and convert it back into heat to supply heat requirements, which could otherwise be supplied direct from fuels without these losses, is certainly not economical. In general, therefore, where heat is required, some two to three times the amount of useful energy can be made available to a customer in the form of gas from a given amount of coal as can be made available in the form of electricity.

Electricity has already obtained a large share of the light and power requirements of most communities. Yet, even when allowing for the fact that 70 per cent of the typical electric company load is used to supply industrial power, and while only 30 per cent of the typical manufactured gas property load is used to supply industrial loads, it is interesting that the energy used in the present typical community in the form of gas is more than in the form of electricity. This is rather surprising. Let us take as a typical example our own company. Our annual kilowatt-hours of electricity sold, including all our industrial power load, is slightly under 400,000,000 kwhr $\times$ 3412 Btu = 1.3 trillion units of energy, while our annual gas load, with its much smaller industrial load, is slightly under 5 billion cubic feet $\times$ 537 Btu = 2.7 trillion units of energy or about twice that of our electric load. After considering the relative efficiencies of utilization by the customer, it is apparent that, while the amount of energy actually used comes closer together, even now we are supplying more useful energy in the form of gas than in the form of electricity. Furthermore, for this somewhat smaller amount of energy our electric customers paid over ten million dollars, while our gas customers paid only a little over four million dollars. The above data are all the more interesting when it is realized that they represent data from manufactured gas in a typical community.

Other Related Factors

Now let us consider some of the other factors that are involved in this subject. It has been shown that gas already is supplying the larger share of the energy in a typical community and that the possibility of supplying this load by electricity undoubtedly looks good to those hydro programs that need load to justify their existence. Let us consider this matter further, showing the effect of such substitution.

The testimony of the National Coal Association before the Senate hearing on July 1 last showed that the present hydroelectric developments are equivalent to 139 million tons of coal a year or 31 per cent of the 1936 bituminous coal production, and that the proposed plants will have a capacity of an additional amount equivalent to 199 million tons a year, or 45 per cent of the 1936 coal production. The combined present and proposed hydro programs equal 338 million tons or 76 per cent of the 1936 coal production.

This should be remembered when we realize the efforts being made by Congress, the Coal Commission, the Guffey Act, etc., to stabilize the large labor-employing coal industry by artificially increasing prices of coal, which can only tend to force coal consumers to go to other forms of fuel. Such action seems pathetic, when greater use of coal, which would result from not developing hydro power, would increase the coal production load factor, reduce the cost of mining coal and tend thereby to broaden the competitive position of coal and increase its application and field of use.

Hydro Development Defeats Employment

The testimony just referred to shows that 50 per cent of the coal freight revenue goes to labor while 65 per cent of the cost of producing coal goes to labor, and that each ton of coal lost by hydro power development represents the loss of one day's labor directly or indirectly employed in production and distribution of coal. Thus, these figures indicate that the total hydro program involves the loss of 338,000,000 days' work, or the work of over a million men steadily 50 weeks a year. It seems that this is indeed a sizable item in our unemployment situation.

Further testimony before the House Appropriations Committee developed the fact that each ton of bituminous coal mined in the United States brings to the miner $1.27 in wages. The labor cost in the production of four barrels of fuel oil (equivalent to one ton of coal) is 68 cents. It also showed that the labor cost in the production of 20,000 cu ft of natural gas (fuel equivalent to a ton of coal) is 8 cents. The labor cost in 2000 kwhr of hydroelectric power (energy equivalent to a ton of coal) is less than one cent.

It would therefore seem folly to develop hydroelectric power (which is one of the worst employers of labor) in a country such as ours, which has adequate coal reserves. The adoption of such policies, in countries like Canada and Sweden, which have no coal reserves, may be justified, even to the extent of subsidizing, but in the United States, where unemployment is our greatest problem and spreading of purchasing power our greatest need, such a development is indeed an entirely different matter. Of course, we cannot stand in the way of progress. If hydro energy, involving a minimum of labor in its production and transportation, can be made available at the market cheaper than energy from coal, in the long run, society as a whole will benefit; even though in the meantime heart-breaking readjustments may be necessary. However, when the reverse is true, at least until we have solved our unemployment situation, an entirely different situation presents itself.

Thus, we can conclude that both from the standpoint of conservation of the irreplaceable and definitely limited mineral forms of energy in our country, and the development of a sound social order, the quicker we develop the uses of coal the better; and the more we develop water power, the more we will delay these factors which are going to bring about our much sought after and apparently elusive "more abundant life."

Liability for Failure to Supply Water

By LEO T. PARKER
Attorney at Law, Cincinnati, Ohio

Frequently, plant engineers are confronted with difficulties resulting from failure of water corporations, or municipalities, to supply adequate water.

Obviously, if either a municipality or a water corporation illegally shuts off water it is liable for the injury or financial loss sustained by the customer. On the other hand, a plant owner may, without liability, be denied water if he fails to abide by reasonable and lawful regulations, city ordinances or state statutes. But if a water supply is shut off under authority of an invalid law or regulation the municipality or water corporation is liable.

The higher courts have consistently held that in operating a waterworks plant, a city is operating a public utility, and must treat all alike within the same classification, and make the same charge for water used. While a city is permitted, within reasonable limits, to classify rates in a practical business manner it must use reasonable classifications. On the other hand, all persons and firms are required to pay a reasonable rate for water, even though the regulation, ordinance or state law undertaking to charge a specific rate may be void.

For illustration, in *Vicksburg Waterworks Company v. Yazoo* (102 Miss. 504) the higher court held that when a consumer is not misled by the neglect of the waterworks company in failing to have an accurate meter to measure correctly the water used by the consumer, the city is not estopped from charging for the amount of water actually consumed. In other words, although a water meter is inaccurate, the municipality or water corporation is not liable for cutting off the water supply from a consumer who refused to pay a reasonable amount for the water actually used, and this quantity may be determined by reference to previous bills rendered.

Conversely, a municipality or water corporation is liable if its employees shut off water to a consumer who refused to pay for water registered by an inaccurate meter, if the consumer is successful in proving that the meter registered a greater quantity of water than actually flowed through it.

Liability for Negligence

A city is liable and cannot be relieved for its negligence in shutting off water. For example, in a leading case (37 N. E. 204) it was shown that a contract existed between a city and its water consumers which gave to the former the right to shut off the water when it became necessary to make extensions or repairs. A plant owner sued the municipality for damages through failure to supply water with which he could make steam. During the trial it was proved that the damages did not arise from intentional failure of the city to supply water, but that a leak in the standpipe was not discovered and there was no longer any pressure in the service pipes. The testimony warranted the inference by the court that due diligence was *not* used by the municipal officials to discover and stop the leaks and to start pumping engines, so as to prevent the standpipe from being emptied. The court held that the city was negligent in failing to discover the leak, and held the plant owner entitled to recover full damages.

Effect of Contract

The courts have held that the right of a consumer to recover damages, resulting from temporarily shutting off the supply of water, need not be based upon an expressed contract between the water company and the consumer. The latest case on this subject is *City of Huntingburg v. Morgan* (162 N. E. 255).

The facts of this case are that a plant owner had been using water for several years. Without any warning to him, the city caused the water pressure in his water pipes to be reduced so that no water would run through them. Such lack of pressure was caused by connecting the water main that supplied his pipes with a new standpipe in which it was intended to store a large quantity of water. The plant owner sued the city for damages and the court held the city liable.

Fire Liability

Negligence or willful misconduct must be proved before liability arises for failure to supply water. However, under ordinary circumstances, neither a municipality nor a water corporation is liable for failure to furnish sufficient water for extinguishing a fire, if no contract exists between the water corporation or municipality and the plant owner. Moreover, various courts have held that a city is not liable in damages to a plant owner whose property is destroyed by fire as a result of negligence on the part of the municipal officials in failing to provide adequate water supply.

For instance, in a leading case (57 S. W. (2d) 793), it was shown that the pumping engine failed to maintain sufficient water pressure to extinguish a fire. The plant owner filed suit to recover damages because the water corporation was under contract with the city to furnish water for its use and for its inhabitants and to maintain adequate pressure for fire purposes. However, the lower court refused to hold the water company liable and the higher court sustained the verdict, saying:

"Many courts of the highest authority hold that an individual inhabitant cannot sue a water company, under circumstances like those here appearing as for a breach of duty to such inhabitant." Other higher courts in several states have upheld this law.

Another important point of law is that a plant owner is entitled to be supplied with water, but he is under a correlative duty to pay the municipality, or water company, according to its rates and in the manner prescribed by its rules. Failure of the owner to do so gives the municipality, or water company, the right to discontinue the supply of water. And if a state law authorizes the municipality, or water company, to a lien of the real property to secure payment for overdue water bills, the seller of water may continue to supply water to delinquent consumers and later hold the owner of the real property responsible for payment of the bill. In other words, under these circumstances a municipality or water company may collect for water supplied to a tenant by either holding the property owner liable or it may cut off the water supply *without notice* if the plant owner refused to abide by reasonable rules.

ORSAT CHECKING CHART

By C. T. JUSTICE

AS THE weak spot in combustion tests is quite often the temperamental Orsat, the chart shown here was devised to check Orsat analyses and to make the meaning of these analyses a little clearer. For instance, if the composition of the fuel being burned is known, Q may be calculated and a line drawn on the chart for this value in the direction of the other Q lines. All flue gas analyses should then fall close to this line when the values of CO_2, O_2 and CO are plotted on the chart. However, the fuel analysis is not usually known and in this case the Q line for the fuel is found by plotting several analyses on the chart and drawing a line in Q direction through the consistent analyses. Orsat analyses of flue gases which contain much CO are very uncertain due to the frequent presence of hydrocarbons in the sample. It might be mentioned here that no method of checking flue gas analyses will detect a leaky sample line as excess air has the same effect on the flue gas sample whether it be introduced in the furnace, the setting or the sample line.

The excess air lines on this chart check very closely with any fuel but blast furnace gas or producer gas. Reasonable amounts of nitrogen in the fuel do not affect the excess air very much. Ten per cent nitrogen by volume in natural gas gives an error in excess air as taken from the chart of less than one per cent. For most purposes, such as checking boiler meters or combustion controls, the excess air as found from this chart is sufficiently ac-

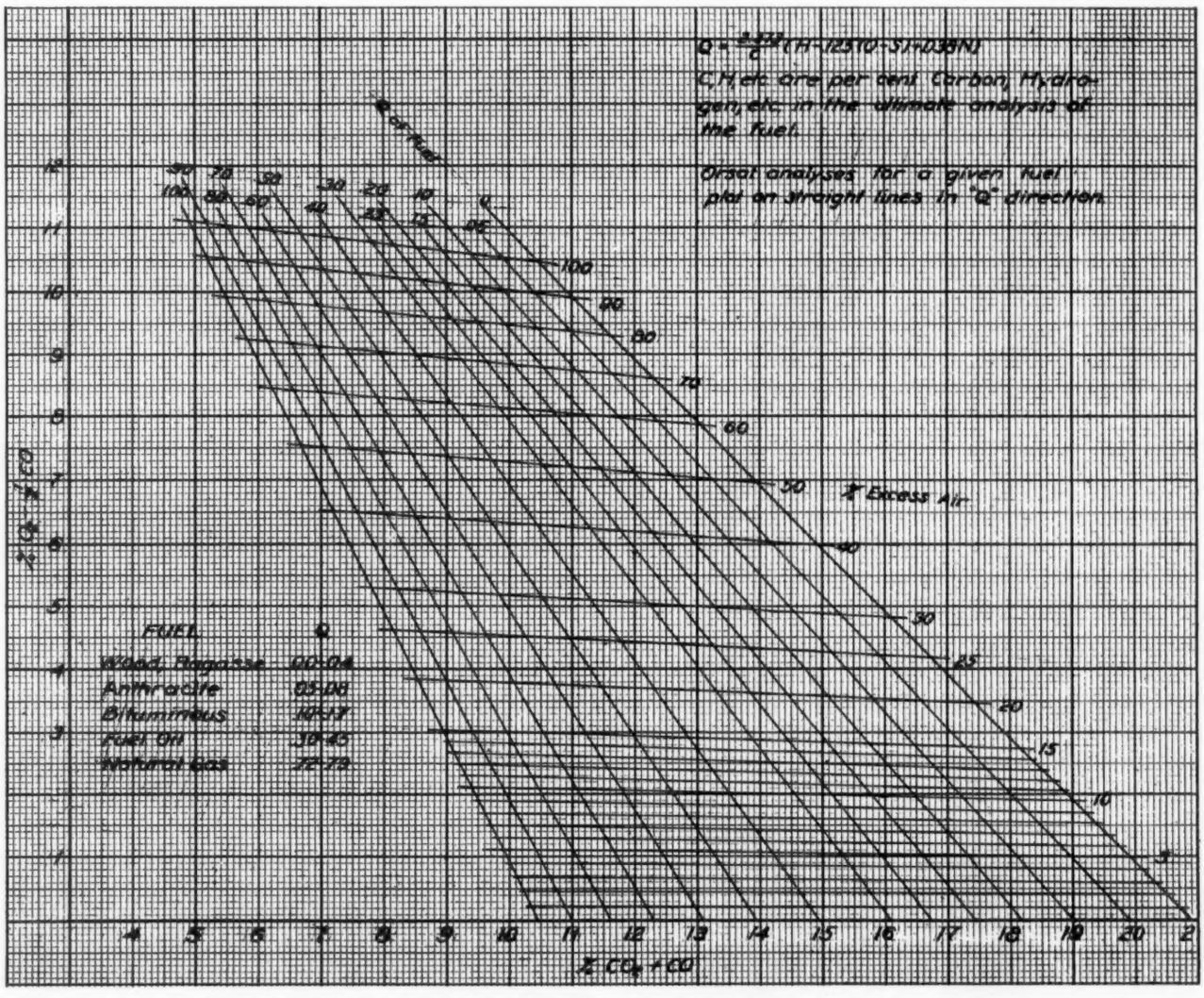

Q = 8.89 C/C (H − 1/8 O − 3/8 N)
C, H, etc. are per cent Carbon, Hydrogen, etc. in the ultimate analysis of the fuel.
Orsat analyses for a given fuel plot on straight lines in "Q" direction.
% Excess Air
% CO2
% CO + CO2
FUEL
Wood, Bagasse
Anthracite
Bituminous
Fuel Oil
Natural Gas

Chart for checking Orsat analyses

curate. The intersection of the Q line for any fuel, with the abscissa or zero excess air line, is the maximum CO_2 that can be attained by combustion of that fuel.

To illustrate the method of using the chart, a flue gas sample taken when burning a West Virginia bituminous coal is to be checked. Below is the analysis of the coal and the flue gas sample:

Coal (Ultimate Analysis, Per Cent)			Flue Gas (Volume Analysis)		
C	=	85.40 (all burned)	CO_2	=	16.0
H	=	5.44	O_2	=	2.4
O	=	6.43	N_2	=	81.6
N	=	1.69			100.0
S	=	1.04			
		100.00			

(Ash and moisture not included)

$$Q = \frac{2.373}{85.40}[5.44 - 0.125\,(6.43 - 1.04) + 0.038 \times 1.69] = 0.162$$

The flue gas analysis, to be correct, must fall on a Q line of 0.16 and, plotting it on the chart, it is seen that this analysis is all right. The excess air found from the chart is about 12.5 per cent, whereas the true excess air calculated for this fuel and flue gas analysis is 12.3 per cent.

When burning coal on grates it will be noticed that Q will vary for different flue gas samples. This is due to stratification of gases from the fuel bed. For instance, a sample of flue gas caught near the rear of a chain grate stoker will show an apparent Q nearer that of pure carbon, and one caught near the front of the stoker (distillation zone) will show an apparently higher Q than the fuel analysis would indicate. In the combustion of two or more fuels in the same furnace the value of Q, as indicated from the flue gas analysis, will give valuable information as to the relative quantities of the fuels being burned, as most often the Q values for the different fuels being burned vary widely.

The Q in the chart is derived from the volumes of dry flue gas (as analyzed in an Orsat) produced by burning unit weights of the various fuel constituents. As used here,

$$Q = \frac{\text{Maximum } CO_2 \text{ with pure carbon}}{\text{Maximum } CO_2 \text{ with fuel in question}} - 1$$

or as maximum CO_2 burning pure C is 20.9

$$Q = \frac{20.9}{\text{Maximum } CO_2 \text{ with fuel in question}} - 1$$

When one pound of any elemental fuel substance is perfectly burned with no excess air there is produced a definite volume of dry flue products. Below is a list of the volumes produced by burning or introducing into the furnace the common constituents of fuels. These volumes are at 14.7 lb absolute pressure and 60 F and perfect combustion is assumed with no excess air.

Volume of Dry Flue Products Produced with Elemental Fuel Substances

C	=	151.2 cu ft of gas per lb
H	=	358.5 cu ft of gas per lb
O	=	−44.8 cu ft of gas per lb
S	=	44.8 cu ft of gas per lb
N	=	13.5 cu ft of gas per lb

When burning a fuel composed of these elements, the total dry products of combustion equal

$$151.2C + 358.5H - 44.8\,(O - S) + 13.5N$$

where C, H, O, S and N are percentages by weight of these elements in the fuel.

As the maximum CO_2 when burning pure C is 20.9 per cent and one pound of C produces 151.2 cu ft of flue gas, the maximum CO_2 produced when burning any fuel is

$$\frac{151.2C}{151.2C + 358.5H - 44.8\,(O - S) + 13.5N}\,20.9$$

$$= \frac{(0.422 \times 20.9)\,C}{0.422C + H - 0.125\,(O - S) + 0.038N}$$

Since $$Q = \frac{20.9}{\text{Maximum } CO_2 \text{ with fuel in question}} - 1$$

$$Q = \frac{20.9}{\dfrac{(0.422 \times 20.9)C}{0.422C + H - 0.125\,(O - S) + 0.038N}} - 1$$

$$Q = \frac{2.373(H - 0.125\,(O - S) + 0.038N)}{C}$$

Personals

J. K. Rummel, Chemical Engineer of the Shanghai Power Company, who has been on leave in this country for several months, has returned to his post in the Orient and in addition to his regular duties will carry on consulting work, in connection with which the facilities of the fully-equipped power company laboratory will be made available.

J. A. Drogue, formerly chief engineer of Ball Bros., Muncie, Ind., is now plant engineer of the Indianapolis plant of the R.C.A.

Theodore Maynz, who for some years had a consulting engineering office in Cleveland and later in New York, has recently been placed in charge of power plants of the American Viscose Corporation. He is located at Wilmington, Del.

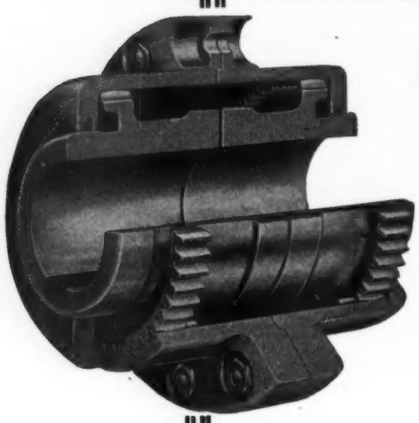
Gerard Swope and **Owen D. Young** will retire on January 1, 1940, after seventeen years of service as president and chairman of the board, respectively, of the General Electric Company. They will be succeeded by **Charles E. Wilson** and **Philip D. Reed.**

Professor A. G. Christie, of The Johns Hopkins University and, until last week, President of the American Society of Mechanical Engineers, has been awarded honorary life membership in The Institution of Mechanical Engineers of Great Britain. **Henry Ford** was a recipient of the same honor.

Lewis H. Brown, President of Johns-Manville Corporation, was presented with the Vermilye Medal on November 14 by The Franklin Institute, Philadelphia, in recognition of outstanding contribution to the field of industrial management.

Edward L. Shea has been elected to the presidency of the North American Company, succeeding **James F. Fogarty** who becomes chairman of the executive committee. Mr. Shea is a graduate civil engineer and until taking over his present duties was executive vice president of Tide Water Associated Oil Company.

POOLE FLEXIBLE COUPLINGS



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INDUSTRIAL INSULATION

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Tests on Steel for Loeffler Boilers at Brimsdown

The two 210,000-lb per hr, 1900-lb pressure, 940-F Loeffler boilers at Brimsdown Station, England, were described in COMBUSTION of July 1939. Further information concerning tests on the steel for these boilers is contained in the August issue of *The Steam Engineer* (London). A brief summary of these requirements follows:

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Maximum stress	32.8 tons per sq in.
Yield point	19.6 tons per sq in.
Extension on 2 in.	33.0 per cent
Reduction of area	59.0 per cent
Izod impact value	99, 94, 91 ft lb

MECHANICAL PROPERTIES AT HIGH TEMPERATURE TENSILE TESTS
(Rate of Strain, 0.06 In. per Min.)

Testing Temperature	Maximum Stress, Tons per Sq In.	0.05% Proof Stress, Tons per Sq In.	Extension on 2 In. %	Reduction of Area, %
950 F	31.3	11.0	30	74
1000 F	29.4	10.3	32	72

IMPACT TESTS AT HIGH TEMPERATURES

Testing Temperature	Impact—Ft Lb
20 C = 68 F	95, 104
100 C = 212 F	121, 123
200 C = 392 F	121, 104
300 C = 572 F	111, 113
400 C = 752 F	85, 89
500 C = 932 F	63, 64
600 C = 1112 F	56, 52

IMPACT TESTS AFTER PROLONGED HEATING (TESTED COLD)

	Impact—Ft Lb
Initial test	94, 94, 99
After 2000 hr at 450 C (842 F)	106, 108, 103
After 2000 hr at 500 C (932 F)	99, 94, 100
After 2000 hr at 550 C (1022 F)	97, 98, 95

Weld and Creep Tests

Numerous mechanical tests were taken and the welds (oxyacetylene process) were sectioned and examined microscopically before the welder's ability and the suitability of the steel were approved. When it came to the actual assembly of the superheaters, X-ray tests were carried out on most of the welds and the joints were normalized after welding by means of a special sectional gas burner.

Owing to the importance of reliable creep data, a series of tests was carried out at the National Physical Laboratory at a temperature of 950 F and 1000 F.

High Steam Temperatures

Engineering and Boiler House Review (London) of October, in an article discussing forced versus natural circulation boilers, presents a table of Sulzer "Monotube" installations, covering 23 units, of which 17 operate at pressures ranging from 1420 to 2000 lb per sq in. While the majority employ moderate total steam temperatures, two installations now under construction, comprising four units, will operate at steam temperatures of 968 F and 986 F, respectively. With this type of boiler and a pressure of 1700 lb per sq in. at the superheater outlet, a feedwater inlet pressure of 2560 lb is required. The units listed are all under 140,000 lb of steam per hour and most of them very much less. They are installed principally in industrial plants, Nos. 4 and 15 being in England and the others in various Continental countries.

SULZER MONOTUBE INDUSTRIAL BOILERS OPERATING, JANUARY 1939

Ref. No.	No. of Boilers	Boiler Output, Tons per Hr	Operating Pressure and Temperature		Method of Firing
			Lb per Sq In.	Deg C	
1	1	7	1420	400	Coal, with Add. Oil Firing
2	1	20	do.	do.	do.
3	1	20	1420	400	Coal
4	2	37	1420	425	Coal
5	1	28	852	Saturated	Coal
6	3*	43	1630	480	Coal
7	1	12	1570	410	Coal
8	1	60	2000	500	Coal
9	1	4	1420	400	Oil
10	1	20	852	400	Oil
11	1	7	570	400	Oil
12	1	10	500	400	Oil
13	1	22	1420	420	Oil
14	1	10	1420	Saturated	Oil
15	2	70	1420	400	P.C.
16	2*	65	1700	520	P.C.
17	2*	70	1630	530	P.C.

* Under construction. P.C. = Pulverized coal.

Back Pressure and Extraction Turbine

In *Die Wärme* of September 1939, there is described a power and process heating plant of a chemical works designed for maximum operating reliability. Of particular interest is the Brown Boveri steam turbine of the extraction and back-pressure type furnishing extraction steam at 190 lb per sq in. abs and back pressure steam at 40 lb abs. The initial steam is at 500 lb per sq in. abs and 790 F temperature and the turbine consumes 28,600 lb per hr with 11,000 lb per hr extraction. Because of the small steam volume a turbine speed of 8000 rpm was selected and the diameters of the wheels and particularly the back-pressure drum were chosen very small so that quite long buckets could be realized and good blade efficiency.

A velocity wheel utilizes the drop from the initial steam condition down to that of the extraction stage. Three nozzle valves admit the steam to the turbine and three additional valves admit the steam remaining after extraction, to the back pressure wheel. The first back pressure buckets are 26 mm long, the radial clearance is about 0.4 mm, and the efficiency is about 85 per cent, even with the clearance loss.

This small clearance is permissible since the ends of the blades are tapered to a knife-sharp edge. The turbine runner is forged of nickel steel. The high-pressure casing is of cast steel and is fastened to the back-pressure portion by a vertical flanged connection.

Regulation is accomplished by oil pressure and in the manner shown in the diagram. The speed governor *a*

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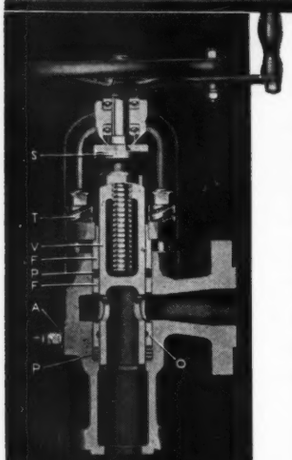

Yarway Seatless Blow-off Valve Operation: After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

Yarway Blow-off Valves are used singly or in tandem in more than 10,000 plants in 67 different industries . . . Regarded as a standard of quality by leading steam plant designers and builders of steam generating equipment . . . Selected for Federal, State and Municipal Institutions . . . Built for all pressures up to 2,000 lbs. . . . Write for Catalog B-417.

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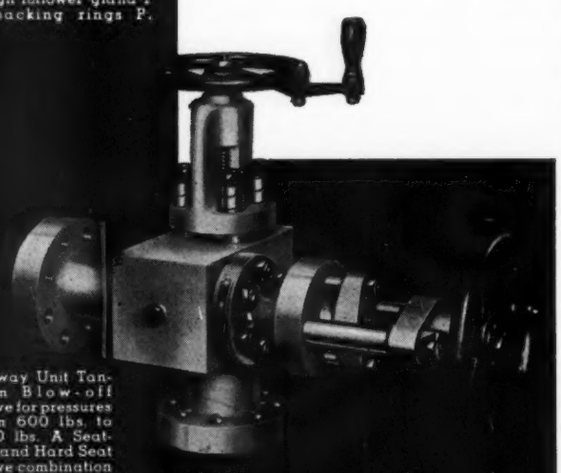

Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

YARWAY BLOW-OFF VALVES

serves only as a limit regulator. Steam admission is controlled by the first pressure regulator *i* which maintains the extraction pressure constant at 190 lb abs

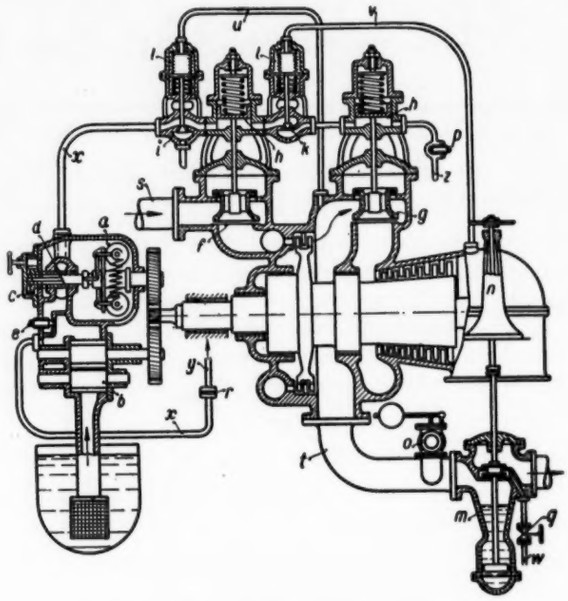

Diagram showing turbine regulation

a = main governor, *b* = gear oil pump, *c* = oil regulating chest, *d* = oil regulating slot, *e* = adjusting screw, *f* = high-pressure steam valve, *g* = cross-flow valve, *h* = power pistons for *f* and *g*, *i* = extraction pressure regulator, *k* = back-pressure regulator, *l* = bellows for *i* and *k*, *m* = stop-and-check valve, *o* = safety valve, *p* = oil drain regulating valve, *q* = drain valve, *r* = diaphragm, *s* = high-pressure steam line, *t* = extraction line, *u* = impuse line to *i*, *v*, = impulse line to *k*, *w* = drain line, *x* = oil pressure line, *y* = to the bearings, *z* = oil drain.

irrespective of steam quantity fluctuations, while pressure regulator *k* maintains the back-pressure constant. The generator is driven at 1500 rpm through reduction gearing.

The turbine-generators are supplied with steam by Sulzer boilers each of 28,600 lb per hr capacity.

Power Station Auxiliaries

An article by T. H. Carr in *Engineering and Boiler House Review* for November discusses current British practice as regards power station auxiliaries. The trend in recent years has been from steam to electric drive, some of the factors mentioned as influencing this trend being:

1. Reduction in piping
2. Better control of the heat cycle
3. Convenience and cleanliness of operation
4. Less maintenance

The voltages employed vary considerably, although in recent years a definite step toward some degree of standardization has been taken. For motors above 200 hp, 3000 volts a c is widely used as a means of saving copper; and below 200 hp, 400 to 600 volts a c or 480 volts d c are generally used, the latter where speed regulation is desired. For very small motors 110 volts d c or 250 volts a c is employed. In some cases motors as large as 700 hp for driving boiler-feed pumps or condenser circulating pumps are switched directly on the line.

Auxiliary power requirements are given in the following table:

AUXILIARY POWER REQUIREMENTS, IN HORSEPOWER

Turbine-generator capacity, kw	30,000	50,000	75,000
Boiler auxiliaries { P.F.	2200	3800	
Boiler auxiliaries { S.F.	1550	2700	3400
Coal and ash handling { P.F.	100	130	
Coal and ash handling { S.F.	120	130	180
Circulating water system	410	600	1000
Turbine-generator	320	620	150*
General station service	150	200	250
Total auxiliaries { P.F.	3180	5350	
Total auxiliaries { S.F.	2550	4250	4980

NOTE: P.F. refers to pulverized fuel and S.F. to stoker firing; also (*) in the case of the 75,000-kw units, turbo-blowers are mounted on the main shaft in place of separate motor-driven fans. The boiler auxiliaries include mill and stoker drives, fans, feed pumps and controls; and the turbine-generator auxiliaries include oil pumps, ventilating fans, extraction pumps and barring-gear drive.

Combustion Engineering Company Amplifies Its Departmental Activities

To meet the present increased volume of potential business, Combustion Engineering Company has extended its departmentation of activities, involving certain reassignments in its organization.

The growing importance of the marine field, due to the present vast construction program for both merchant and naval vessels, has made necessary increased personnel in the company's Marine Department, of which Commander H. T. Dyer is manager; and, in view of the particular adaptability of the La Mont steam generator to marine installations, W. H. Armacost has been given the responsibility for engineering development in this department, in addition to his previous duties in connection with stationary equipment. H. S. Colby, for the past five years General Sales Manager of the company, has been delegated with executive responsibility for the conduct of the company's marine business and will devote his entire time to that work.

Donald S. Walker, formerly manager of the Philadelphia district, has been appointed General Sales Manager. He will be assisted by Otto deLorenzi and H. G. Ebdon, the latter formerly of the New York District Sales Office, as Assistant General Sales Managers.

College of Engineering at Duke

In accordance with a resolution adopted by the Board of Trustees of Duke University, the Division of Engineering, which was administered as part of Trinity College, has been reorganized into the College of Engineering of Duke University. W. H. Hall, Professor of Civil Engineering and Chairman of the Division of Engineering, has been appointed Dean of Engineering. Three curricula in engineering, civil, electrical and mechanical, are offered. The enrollment, which has been set at a maximum of 225, is now 216.

Theory of Evaporation

The "Kinetic Theory of Evaporation" will be the subject of a talk by Dr. E. F. Leib, of Combustion Engineering Company, before the Metropolitan Section of the A.S.M.E. on the evening of January 4. The lecture is sponsored by the Applied Mechanics Division of the Society.

WHAT

Steam Plant Equipment to buy, and WHEN TO BUY IT?

—before that question comes up, as it does eventually in every industrial plant, it pays to get completely disinterested advice from an organization which has back of it years of experience gained from analyzing hundreds of steam plants, and from watching those plants *operate;* one which knows the fuel markets in detail and in long perspective, and *one which has nothing to sell.*

Steam plant improvement should be a matter of long range policy, rather than one of year-to-year expediency. Our job is to get the facts and to interpret them realistically. We are paid to do that job, and we have no financial interest in whether or not you spend any money on your power plant, or in when you spend it.

An inexpensive preliminary study will quickly reveal whether or not your situation has in it the possibilities of a profitable investment, within the limits of financial policy, and to what extent further investigation is justified to provide a basis for a definite power policy.

Such a program is insurance against hasty decisions, based on expediency, and piece-meal improvements, which so often in the end only amount to throwing good money after bad. And yet, step-by-step modernization can be made very profitable, when each step is part of a long range plan.

More and more industrial executives are calling on our staff for just this kind of professional assistance, for the very reason that we do *not* design or build plants, or supervise construction.

Just as we believe that preliminary planning is definitely within the field of applied fuel engineering, we also believe that the design and construction of plants should be in the hands of those professional organizations whose experience lies in that field.

Our staff is available for investigation, and consultation on any matter related to the building or alteration of power plants, or the selection of steam plant equipment. It pays to study the question before new investment becomes urgent.

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MILWAUKEE-WESTERN FUEL COMPANY, Milwaukee, Wisconsin.

EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

	1939 Water Tube No.	1939 Water Tube Sq Ft	1938 Water Tube No.	1938 Water Tube Sq Ft	1939 Fire Tube No.	1939 Fire Tube Sq Ft	1938 Fire Tube No.	1938 Fire Tube Sq Ft
Jan.....	75‡	380,903‡	52	201,151	50‡	64,511‡	35	42,752
Feb.....	70	309,235	48	185,257	45	58,028	45	55,173
Mar.....	98‡	386,132‡	58‡	238,830‡	58	54,752	50	49,039
Apr.....	62	276,507	48	195,910	36	42,177	37	52,421
May.....	104	406,828	60	330,653	74	96,037	61	68,288
June.....	99	486,631	58	190,242	52	58,793	63	86,975
July.....	88	320,901	67	271,561	59	66,595	69	98,074
Aug.....	88	397,093	56	190,762	52	55,714	53	69,494
Sept.....	136	715,911	45	169,241	74	110,082	58	62,794
Oct.....	118	596,509	51	191,932	58	71,060	46	48,231
Jan.-Oct., Inclusive..	938	4,276,650	543‡	2,165,539‡	558	677,749	517	633,241

‡ Revised.

Mechanical Stoker* Sales

	1939 Water Tube No.	1939 Water Tube Hp	1938 Water Tube No.	1938 Water Tube Hp	1939 Fire Tube No.	1939 Fire Tube Hp	1938 Fire Tube No.	1938 Fire Tube Hp
Jan.....	44	17,067	28	9,484	145	17,842	76	10,991
Feb.....	46	20,715	36‡	12,450‡	140	18,217	76‡	12,216‡
Mar.....	46‡	19,068‡	54	18,820	122	15,743	52	9,434
Apr.....	50	18,888	35	12,698	114	13,652	71	11,058
May.....	62	29,245	32	10,830	153	20,010	106	15,342
June.....	83	34,618	28	9,284	184	21,801	166	21,378
July.....	66	20,893	45	17,449	213	30,829	191	24,816
Aug.....	65	22,589	35	10,991	311	41,310	269	33,199
Sept.....	94	40,983	47	16,250	345	45,731	279	28,780
Oct.....	63	23,480	42	15,809	313	39,784	300	44,111
Jan.-Oct., Inclusive..	619	247,546	382	134,065	2,040	264,919	1,586	211,325

* Capacity over 300 lb of coal per hour. ‡ Revised.

Pulverizer Sales

	1939 Water Tube No. N.†	E.†	Lb Coal/Hr	1938 Water Tube No. N.†	E.†	Lb Coal/Hr	1939 Fire Tube No. N.†	E.†	Lb Coal/Hr	1938 Fire Tube No. N.†	E.†	Lb Coal/Hr
Jan...	10	—	79,000	5	—	40,500	—	—	—	1	—	1,000
Feb...	7	—	89,600	7	1	38,020	—	—	—	—	1	800
Mar...	26	—	483,560	—	2	26,100	—	—	—	—	1	700
Apr...	8	—	155,050	2	2	26,200	—	—	—	—	—	—
May..	19	—	401,800	5	2	33,690	—	3	1,800	—	—	—
June..	19‡	1	297,230‡	7	2	49,440	—	—	—	—	—	—
July...	6	—	43,770	3	1	23,000	—	—	—	—	—	—
Aug...	3	4	53,700	8	5	155,390	—	—	—	1	—	1,000
Sept...	33	11	556,430	2	1	58,500	1	—	1,250	—	—	—
Oct...	26	2	419,410	2	—	7,650	1	—	2,800	—	—	—
Jan.-Oct. Inclusive.	154‡	18	2,525,550‡	41	16	458,890	2	3	5,850	2	2	3,500

† N—New boilers; E—Existing boilers. ‡ Revised.